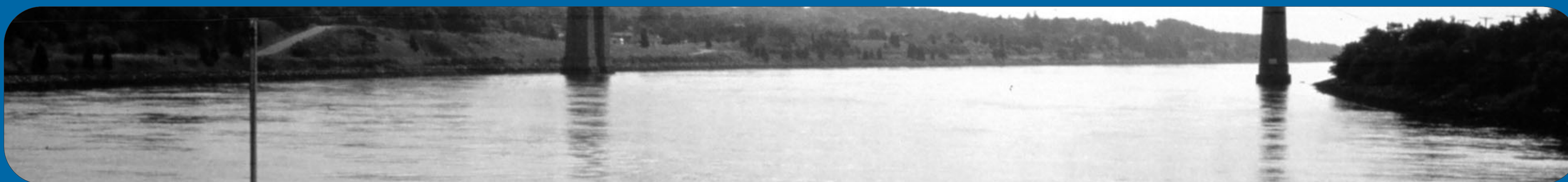
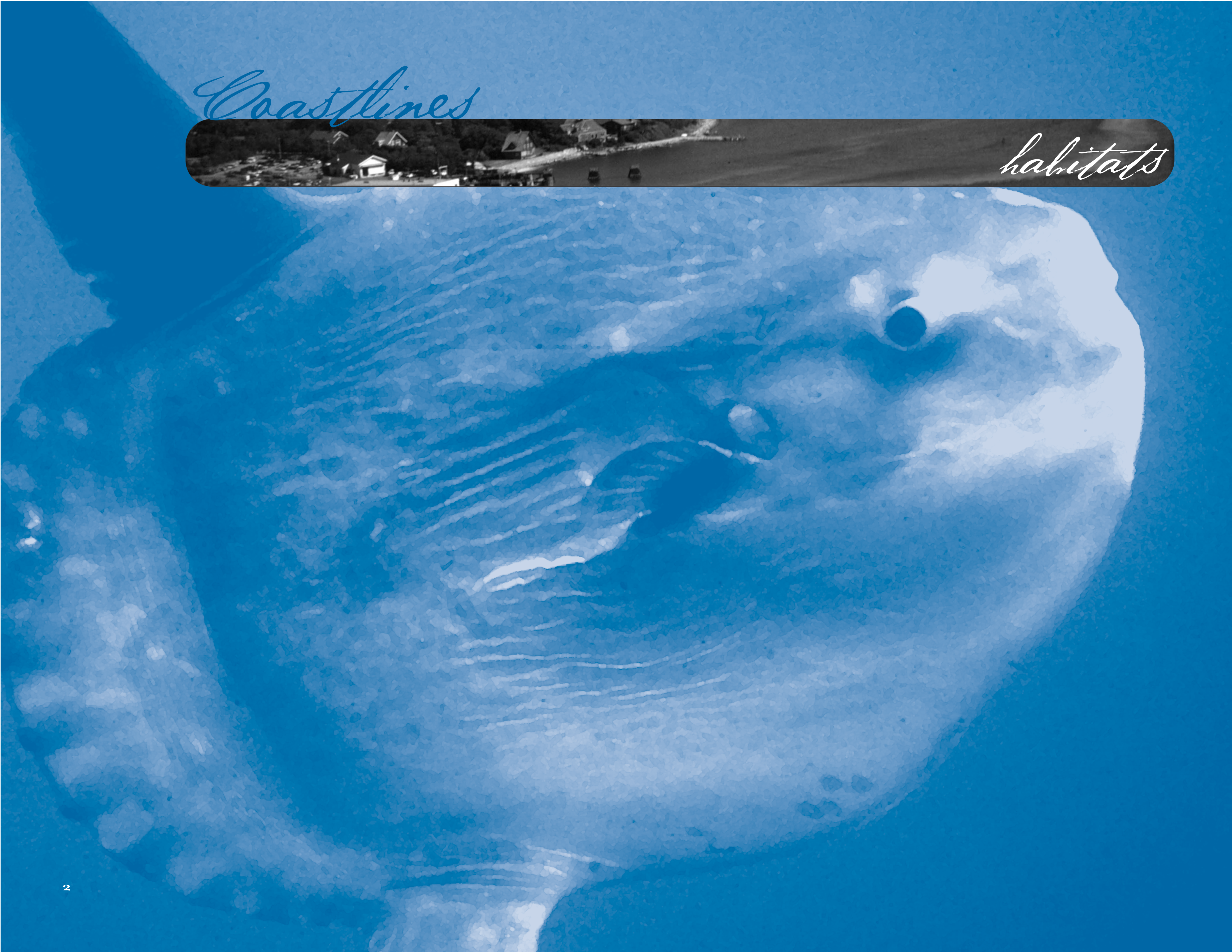
feature

Marine & Coastal Habitats of the Commonwealth



MORE THAN A HOME, a habitat is an area that provides everything an animal or plant needs to survive. This edition of *Coastlines* focuses on the Bay State's marine and coastal habitats and explores the major habitat types, important and interesting species and their habitats, habitat mapping and monitoring techniques, and the management measures used to protect these habitats in Massachusetts.

Coastlines habitats



From Dune to Shining Sea:

The Coastal and Marine Habitats of Massachusetts

By Anne Donovan and Dr. Megan Tyrrell, CZM

The Commonwealth's coastal zone encompasses 78 communities, 1,500 miles of shoreline, 2,500 square miles of ocean and bay (an area roughly half the size of Rhode Island), and dozens of habitats. From open water to salt marsh to sandy dune, these habitats provide the plant and animal species of this region with their requirements for life, including food, shelter, and the basic conditions for survival (appropriate ranges of temperature, salinity, oxygen, etc.).

Massachusetts is blessed with a wide variety of marine habitats—largely due to its unique geographic and geologic position. During the last major ice age 35,000 years ago, three great glaciers expanded from the north, slowly moving southwestward, scouring the landforms below and collecting and carrying debris of all kinds. When the weather warmed and the ice floes melted 14,000-18,000 years ago, this accumulated debris was left behind, forming a distinct boundary between the lands scoured by this tremendous force of nature and those where the collected materials were deposited. The flexed "arm" of Cape Cod marks the boundary between the two distinct regions created, the Acadian province to the north and the Virginian province to the south. By scouring soft sediments from the surface, the glaciers left northern New England with its characteristic rocky coast. In contrast, the sediments deposited from the Cape southward created the sandy beaches, mudflats, and other soft-sediment habitats common to this region.

While the geologic raw materials of a rocky coast, sandy beach, or mud flat are vitally important in determining habitat type, the vegetation present is often of equal importance, particularly in the cases of seagrass beds, salt marsh, and kelp forests. Some animals also serve as habitat for other organisms. For example, shellfish beds found on soft sediments provide hard surfaces for a diverse community of plants and animals that need this kind of surface for anchoring. These geologic and biologic features, along with a host of chemical and physical characteristics, create the diversity of habitat types found along the Commonwealth's coast and under the ocean's surface. This article will cover the most

Rock on: The North Shore of Massachusetts is known for its rocky coast.

another angle

Quidquid Latine Dictum Sit, Altum Viditur* *By Ardenteus Millerucus*

Once upon a time in a land where most of the population worked the land, farm animals slept indoors (sometimes even in the communal family bed), and the average life expectancy was 40, Latin was *the* language used by educated (or, as they said then, *learned*) men and priests—hence the official means of communication between countries. Throughout the middle ages and up until the early 1600s, in order to gain admittance to a university one had to speak and write Latin. The connection between Latin and higher education has continued to this day, ensuring that future generations of prep school graduates know that *semper ubi sub-ubi* means always wear underwear…

While it's been said that Latin is a "dead language," any reports of its death are greatly exaggerated. Not only does Latin serve as the basis for the Romance languages—French, Spanish, Italian, Romanian, and Portuguese—but many familiar phrases are undiluted, straight-up, old-school Latin. Some such terms are: *alter ego; bona fide; persona non grata; ad nauseam; carpe diem; alma mater; pro bono; curriculum vitae; vice versa; terra firma; quid pro quo; mea culpa; per diem;* and *et cetera*. And let's not overlook the ubiquitous e.g.—*exempli gratia*, meaning "for the sake of example"—and its oft confused cousin i.e. (Latin for *id est*, meaning that is). These *examplis* are proof that Latin is alive and, well, well-used, in today's vernacular.

But beyond the Latin words and phrases that live on and pepper our conversations in A.D. 2005 (*anno Domini*—yes, *more* Latin), in the scientific world Latin is the foremost identifier of flora and fauna. Why Latin when, centuries ago, French replaced Latin as the *linguage du jour* (interestingly enough, this was referred to as the "*lingua franca*," or common language, at the time) and, since then, English has become the Unix system of languages? By using the universal language of scholars, scientific researchers could be sure that if they identified a *Larus argentatus* in Prague, a colleague in Helsinki would know that they saw a Herring Gull.

The convention of using a binomial, or two-word, naming system was established in 1753, when Carolus Linnaeus, a Swedish physicist and naturalist, published *Species Plantarus* (plant species). It worked (and still works) like this: the first identifier is the genus (a group of related species)—e.g. *Rosa* is a rose—and the second moniker identifies the specific species within that group of species. Hence, a rose by another name could be a *Rosa centifolia* (cabbage rose) or a *Rosa damascena* (damask rose), or a *Rosa rugosa* (Japanese rose).

For the purposes of these articles, all species are identified with their English name, followed by the Latin genus and species name, in italic. When the species is mentioned a second time, just the English name is given. So, don't say "It's all Greek to me!," because it's more likely Latin…

*Anything said in Latin sounds profound

prominent of these habitats, which include seagrass beds, salt marshes, kelp beds, shellfish beds, sandy sediments, rock, mud, and the water column.

SEAGRASS BEDS

Description: Seagrass forms flowing meadows and distinct patches of swaying fronds that are typically submerged by the sea (although occasionally some plants grow in areas that area periodically exposed by the tide). The roots of seagrasses anchor the plant to the sediment, while (unlike most terrestrial plants) nutrient absorption occurs throughout the stems and leaves. In Massachusetts, eelgrass (*Zostera marina*) is the most common species; widgeon grass (*Ruppia maritima*) can be found in areas of reduced salinity in Cape Cod Bay and Buzzards Bay. Eelgrass can grow in bottom sediments ranging from coarse sand to mud, but requires clear water to ensure the light penetration needed for its survival, as well as protection from the battering of waves and storms. Large, contiguous tracts of seagrass are visible in aerial photographs and the state's Department of Environmental Protection is using aerial photography to map the distribution of seagrass beds along the Commonwealth's coast. Currently, the largest contiguous beds of seagrass in Massachusetts are found along the southern shore of Cape Cod and in Cape Cod Bay near Wellfleet Harbor.

Importance: One of the most productive marine habitat types, seagrasses rival the productivity of intensively managed farmland (Thayer et al. 1984). Seagrasses produce oxygen, which benefits the animals that live in the beds, and improve water quality by absorbing nutrients. The plants also provide physical structure that would not otherwise be available in the sand and mud, sheltering small fish, crustaceans (such as shrimp, crabs, and other hard-shelled aquatic species), and other animals, and serving as attachment surfaces for invertebrates (animals without backbones) and epiphytic algae (algae that are specialized to live on other plants). This structure raises local species diversity, and studies in New England have documented 40 species of fish living in eelgrass beds. Seagrass beds are particularly important nursery areas for commercially valuable species such as bay scallops (*Argopecten irradians*), blue mussels (*Mytilus edulis*), and winter flounder (*Pseudopleuronectes americanus*). The "wasting disease" outbreak along the Atlantic coast in the 1930s, which killed an estimated 90 percent of the eelgrass in the region, underscores the importance of eelgrass beds. Massive erosion of sediments and changes in water quality followed the eelgrass dieoff, with animals (including waterfowl and shellfish) that depend on eelgrass beds for both food and shelter suffering large mortalities.

Threats: These submerged plants need sunlight to survive. Decreased water clarity due to dredging, pollution, and boating activity are therefore a direct threat, as is shading from docks and piers. Physical damage from fishing, boating, and dredging can also harm seagrass beds. The most widespread current threat, however, comes from the excess input of nitrogen into estuarine and marine systems. Runoff from agricultural lands, fertilized lawns, septic systems, and other sources carries nitrogen into seagrass beds, stimulating the growth of phytoplankton and other vegetation that cloud the water and shade out the seagrass.

SALT MARSHES

Description: These low-lying vegetated wetlands are subject to the tides, with a distinct low marsh area (flooded twice daily) and a high marsh area (which is submerged only during storms and extreme high tides called spring tides). In Massachusetts, the low marsh is dominated by the tall form of salt marsh cordgrass (*Spartina alterniflora*), while the high marsh is usually composed of a mix of salt tolerant plant species including the short form of salt marsh cordgrass, salt meadow hay (*S. patens*), black grass or rush (*Juncus gerardii*), and spikegrass (*Distichlis spicata*). Some of the common salt marsh animal inhabitants include: mummichogs (*Fundulus heteroclitus*), striped bass (*Morone saxatilis*), quahogs (*Mercenaria mercenaria*), mussels, oysters, snails, green crabs (*Carcinus maenas*), and fiddler crabs.

Importance: One of the most productive environments on earth, salt marshes serve as important nursery grounds and wildlife habitat. Commercial species that use salt marsh as breeding or nursery habitat include menhaden (*Brevoortia tyrannus*), winter flounder, and striped bass. Animals and plants living beyond salt marsh borders also benefit from their productivity as tides carry nutrients and decayed plant materials from the marsh to surrounding areas, fueling other marine food webs. When fish and crustaceans feed in salt marshes and then move offshore and become prey, they also transfer energy from the marsh to these other environments and their resident animals. These dynamic ecosystems provide tremendous additional benefits for humans including flood and erosion control, water quality improvements, and opportunities for recreation.

Threats: Polluted runoff from upland development is a major threat to salt marshes, contributing contaminants that harm the plants and excessive nutrients that stimulate the growth of algae. Sea level rise is also an increasingly prominent issue, potentially

a, B, c, d ... "B" Is for Bird

The highly attentive *Coastlines* reader may have noticed something strange in the naming convention we are using for common species. For most animals and plants, such as diamondback terrapin, moon snail, and salt marsh cordgrass, we are not capitalizing the common name. As with most things in life, however, there is one exception—birds. Ornithologists have adopted a different naming convention than other disciplines, choosing to capitalize common names. Consequently, Least Tern, Herring Gull, Piping Plover, and all the rest of their feathered friends are capitalized in CZM publications.

photo by Arden Miller

Salt of the Earth: Salt marshes are one of the most productive habitats on earth! For many fish and crustaceans, salt marshes are both breeding ground and nursery.

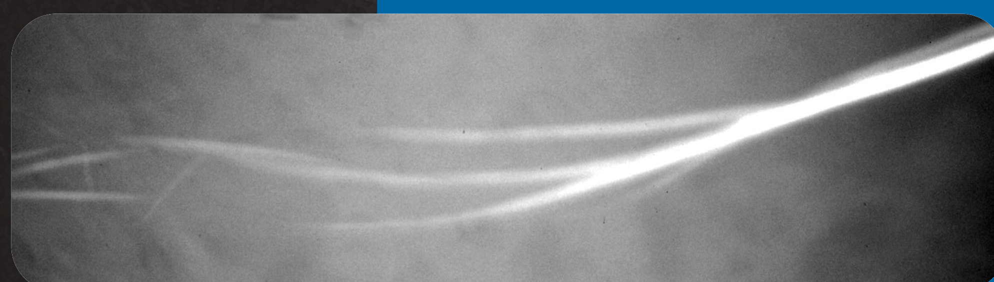
The Habitat Connection *By Anne Donovan, CZM*

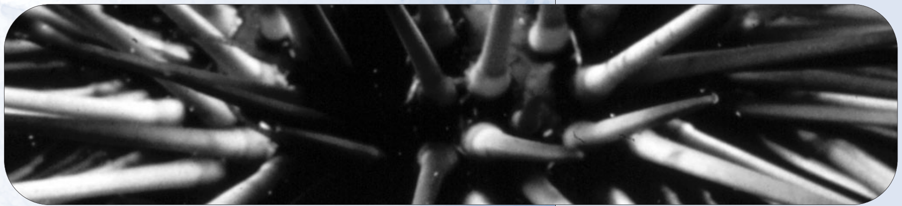
"It's all connected"—an established commandment of environmentalism. This concept also holds true for marine and coastal habitats, connected to each other through the water cycle where rain and snowmelt flow overland and/or underground to rivers, streams, and directly into the sea. Tides, waves, and currents further transport materials through the water and along the shore.

The result is an interconnected web of habitats where nutrients, sediment, and even pollution are transferred from place to place, changing the habitats along the way. For example, the great plant productivity in salt marshes generates large quantities of nutrients, which are flushed away by the tide and then nourish nearby estuaries, bays, and even open ocean ecosystems. This nutrient exchange enhances the growth of rooted and free-floating plants, forming the basis of the food web in these areas. When sediments (including sand, mud, and silt) are carried to rivers and streams that wash them to the sea, larger particles settle out closer to shore, while smaller, lighter particles are carried further, settling to the bottom in quiet waters. Sediments and contaminants are also connected, with pollutants often adhering to fine-grained sediments. Similar pathways carry pesticides, oil, and other pollutants from stormwater discharges, urban runoff, and other sources throughout marine and coastal habitats.

The animals and plants of coastal and marine environments are also free to move from one habitat to the next. As discussed in *Moving on Up (and Down): Habitats of the Lobster Lifecycle* on page 14, many species spend different stages of their lifecycle in various habitats and require a range of habitats to survive. This concept is particularly important when it comes to nursery grounds—the coastal and marine habitats with ready hiding and feeding places for larvae and young. Whether it's the densely packed sheaths of eelgrass or salt marsh, swaying fronds of a kelp bed, or dark spaces among cobble, nursery areas provide biological and/or geological structure that protect progeny from predators. With many species, as the young grow, they spread out and populate new habitats that meet their changing needs.

Holy crustacean habitat hideout, Batman! In Massachusetts, Zostera marina—er, eelgrass—is the most common of the seagrasses.





Moveable munching machines: Sea urchins are known to feast on kelp.

drowning salt marsh plants. In addition, although the Massachusetts Wetlands Protection Act has prevented the outright destruction of salt marshes and other wetlands since 1963, the legacy of detrimental wetland impacts remains visible in the undersized culverts below roads and railways that prevent adequate salt-water flow into these environments. (See *Joint Ventures and Adventures in Coastal Wetlands Restoration* on page 48 for details on how CZM's Wetlands Restoration Program is addressing this issue.) The reduced salinity alters the plant community and facilitates the spread of the invasive reed *Phragmites australis* (note, this particular species does not have a consistent common name in this region so will be referred to as Phragmites throughout this article), which out-competes other salt marsh vegetation including salt meadow hay. Because of its lower habitat value for many species, biodiversity is reduced in areas where Phragmites becomes dominant. Docks and piers that span the width of the salt marsh shade the vegetation and can cause reduced growth rates or death of the plants.

KELP BEDS

Description: Many species of algae (familiar to most people as seaweed) inhabit the rocky subtidal zone, but kelp beds form a distinctive habitat type. In Massachusetts, the most common species of these brown algae are sugar kelp (*Laminaria saccharina*), oarweed (*L. digitalis*), and shotgun kelp (*Agarum clathratum*). These local kelp species can grow to about 10 feet in height, while off the U.S. Pacific coast, some kelp species can reach 10 times the size of Atlantic coast kelps. Like most of the subtidal habitats in Massachusetts, the location of kelp beds has not yet been mapped. Kelp beds are generally found attached to stable rock substrates in clear, cold waters, however, and are most likely limited to subtidal rocky areas north of Cape Cod. Kelps can also attach to human-made structures such as docks and piers.

Importance: Like underwater forests, kelp beds provide the same type of physical structure as trees on land. This structure serves as a refuge for a diverse array of invertebrates and fish and provides shelter from physical stresses including ultraviolet radiation from the sun and strong currents. The holdfasts, or root-like structures, harbor their own mini-world, serving as habitat for a host of small invertebrates, including brittle stars and juvenile mussels. With one of the highest primary productivity rates in the world, kelp beds also cycle nutrients (i.e., they use the energy of the sun and nutrients in the water column to produce plant material, which is then eaten by a variety of underwater animals). Extensive kelp beds reduce current speeds and buffer upland areas from erosion and storm damage.

Threats: Population explosions of herbivorous green sea urchins (*Strongylocentrotus droebachiensis*) led to

Mussel Beach: Byssal threads abound in this rocky mussel habitat.

destruction of kelp beds in many parts of the Gulf of Maine in the late 1980s and 1990s. Some scientists attributed the drastic increase in sea urchins to overfishing of groundfish that consume urchins. (Although this problem continues, the overfishing of sea urchins has somewhat reduced the pressure on kelp.) Kelps are also particularly susceptible to overgrowth by several introduced species, including the lacy crust bryozoan (*Membranipora membranacea*), which slows kelp growth rates by reducing light penetration. These bumpy, crust-like animals also increase the friction of the kelp surface, making it more likely that the algae will be dislodged by storm waves. Reduced water quality, especially increased sedimentation, also slows kelp growth rates by blocking light penetration. Finally, in some areas in the Gulf of Maine, kelp beds are being replaced by the introduced green fleece algae (*Codium fragile ssp. tomentosoides*) causing a major change in the physical structure of the seafloor with the bushy growth of green fleece algae supporting a very different biological community than the tree-like structure of kelp.

SHELLFISH BEDS

Description: In dense groupings, bivalve mollusks, including oysters, scallops, quahogs, and soft-shell clams (*Mya arenaria*), form a habitat type known as shellfish beds. Small organisms, such as polychaete worms, juvenile crabs, snails, and seastars, find refuge in the spaces between the shells, while other organisms, including slippershells (*Crepidula fornicata*), sponges, hydroids (polyp-like invertebrates that grow in clusters), algae, and bryozoans (invertebrates that attach to hard surfaces and form branching, rubbery, or encrusting colonies), attach to the shells' hard surfaces, which provide an anchor unavailable in the surrounding soft sediments. Each species of bed-forming shellfish has different habitat requirements, which means that shellfish beds can be found in a range of depths, salinities, or substrates (surfaces, such as sand, rock, or mud). The way these creatures aggregate also affects the type of habitat they provide for other species. For example, Eastern oysters (*Crassostrea virginica*) cement themselves together forming a reef. Blue mussels bind together by secreting strong, flexible byssal threads (the strong, thread-like substance used to anchor the mussel). Along with keeping the bed intact, these byssal threads serve another fascinating purpose—defense. When a slow-moving predator like a dogwhelk (*Nucella lapillus*) attempts to feed on a mussel, the mussel releases chemical cues that warn its neighbors of the attack. The other mussels then secrete byssal threads in an attempt to capture and secure the predator. When exploring mussel beds, it is not uncommon to find dogwhelk shells enclosed in this final byssal thread death grip. Many other species, such as scallops, soft-shell clams, and surf clams, do not attach to each other but their dense aggregations are nevertheless referred to as shellfish beds.

Importance: Humans, crabs, lobsters, fish, and diving seabirds all consume large quantities of shellfish. For coastal residents and tourists, clamming is an important pastime, while for commercial fishermen in Massachusetts, shellfish beds support a significant fishery. Through filter-feeding, shellfish improve water quality by removing suspended material and particulate pollutants from the water column. Shellfish beds also provide an important link between benthic (bottom) and pelagic (open water) habitats by capturing small food particles from the water column and transferring them to the benthos.

Threats: Reduced water quality is the biggest threat to nearshore shellfish beds, with high levels of nutrients, excessive sedimentation, toxics, and increased water temperatures all factors that contribute to diminished water quality. Outbreaks of disease and parasites have been implicated in the severe declines of coastal oyster populations, and reduced water quality and increased salinity are thought to contribute to the success of these pathogens. Overfishing of shellfish can also diminish their filtering function, potentially leading to increased turbidity (cloudiness due to sediments or other substances in the water) and diminished light penetration to the seafloor. Shellfish beds can be destroyed if they are dredged or if dredged material is deposited nearby or in upstream locations. Bottom-tending fishing gear, such as trawls, also harm shellfish beds through direct physical damage and re-suspension of sediments, which can slow growth rates or even smother filter-feeding shellfish.

SANDY SEDIMENTS

Description: From the dunes rising above the high tide line, through the intertidal beach, to the sandy reaches below the surf, sand habitats are important in Massachusetts, particularly south of Boston. In these highly dynamic environments, sand is moved by tides, winds, and storm surges, and this movement is responsible for shaping these habitats. Dunes are created when sand blown from beaches is trapped by beachgrass or other objects, while beaches—as well as the areas below the surf—change over time and from season to season as waves and tides transport sand from one place to another. During the stormy winter season, larger, more energetic waves carry sand offshore, leaving a steeper beach profile. In contrast, the relatively gentle waves of summer redistribute the sand on a local scale, leaving a gently sloping, wide beach. In areas constantly submerged by the sea (i.e., the subtidal zone), sandy bottoms can be relatively flat with small ripples, or strong currents can shape the sand into long, undulating sand waves.

another angle

Beach Profiles:

Who's Who on the Beach and Beyond *By Megan Tyrrell and Anne Donovan, CZM*

Mermaid's Purse - Every child who's ever walked a Bay State beach has wondered about this rubbery, black casing with double digits extending from either end. Known as a "mermaid's purse," it is actually an egg case from a skate. Upon careful examination, you may even be able to find the small opening where the baby skate emerged.

Northern Moon Snail - This large, predatory snail (*Euspira heros*) lives on sandy bottoms in the subtidal zone and inspires curiosity in beachcombers by leaving behind sandy collars frequently found in the shallows. These rubbery, circular formations are the snail's egg cases.

Channeled Whelk - Like the moon snail, this predatory gastropod of the sandy subtidal (*Busycon canaliculatum*) leaves an egg casing for the imaginative to contemplate—this one looking like a curling, rubbery backbone.

Sand Dollar - Another common inhabitant of sandy bottoms, *Echinarachnius parma* are deep red to an almost-black purple, covered with fine hair-like spines when alive. Once dead, they lose the spines and this coloration, going gray, until washed onto the beach. In the heat of the sun, they bleach to a beautiful bone white.

Slipper Shell - Like the name implies, the shells of *Crepidula fornicata* look something like inside-out slippers—an outside cup with an inside shelf extending halfway over the bottom. They attach to hard surfaces, often to the outside of other mollusk shells or rocks. They are also found stacked on top of each other in a mating embrace complete with a sex-change twist—the slipper shells on the bottom become female, the ones on the top become male, and the ones in the middle are hermaphroditic.

Lady or Calico Crab - Although *Ovalipes ocellatus* does bury itself in sand, unlike many other crabs in this region, it can swim using paddle-like back legs. This aggressive and fast moving crab has a pink, mottled carapace (i.e., shell) with a delicate scalloped edge.

Jingle Shell - Also known as Mermaid's toenail, *Anomia simplex* may be most commonly known as a component of wind chimes, with these light-weight shells making pleasant tinkling sounds when hit together. After big storms, the beach is littered with windrows of jingle shells, with their distinct curved top shell and flat bottom complete with hole for byssal threads to attach to a solid object. The glossy, semi-translucent shells come in a variety of colors: silver, yellow, orange.

Razor Clam - Commonly known for its unusual shell, shaped like an old-fashioned razor, *Ensis directus* is one of the fastest burrowers in the clam world. Although rarely found on any menu, its meat is edible.

Bay Scallop - Giving new meaning to "old blue eyes," *Aquipecten irradians* has a row of bright blue eyes that line the edge of each shell. It is also an accomplished swimmer, using its powerful adductor muscle (the only part of the scallop that we eat) to flap its two shells together. By directing the resulting current, these mobile shellfish can move in almost any direction.

The Frank Sinatra of the crustacean world: Scallops have bright blue eyes! Now, if only they could sing...

The shifting sands of this dune are home to tenacious beach vegetation.

photo CZM archives

Beach babes: Northern Harrier Hawks, Piping Plovers, Least Terns, and diamondback terrapins (above), among others, use sand dunes for nesting.

Importance: The coastal habitat type that is most intensively used by humans for recreation, sandy beaches and the frequently abutting dunes also provide habitat to many endangered and threatened species. Bird species that nest in sand dunes or upper sections of sandy beaches include the endangered Roseate Tern (*Sterna dougallii*); the threatened Northern Harrier hawk (*Circus cyaneus*) and Piping Plover (*Charadrius melodus*); and the Common Tern (*Sterna hirundo*) and Least Tern (*S. antillarum*), which are both listed in Massachusetts as species of special concern. The threatened diamondback terrapin (*Melaclemys terrapin*) also uses sand dunes for nesting. Dunes and beaches also protect inland areas from storm surge and wind. On sandy beaches, amphipods (commonly known as beach hoppers) consume the decaying plant and animal material left by the retreating tide, and are in turn consumed by birds. Although sand-dominated habitats have relatively low rates of plant growth, they are important as foraging grounds for shorebirds, fish, and crabs.

On the seafloor, below the reaches of the tide, few organisms remain exposed in flat, sandy areas. Instead, they generally bury beneath the sand to avoid predators and currents. Some burying species include moon snails, whelks, sand dollars (*Echinarachnius parma*), and American sand lances (*Ammodytes americanus*). Another adaptation common among subtidal sandy bottom inhabitants is camouflage—flounder, gobies, skates, and shrimp are especially difficult to see against the sand. Other species, such as silver hake (*Merluccius bilinearis*), are commonly found within ripples in the sand, which provide protection from currents and cover for ambushing prey (Auster et al. 2003). A variety of shellfish and crustaceans inhabit subtidal sandy areas, including surf clams (*Spisula solidissima*), coquina clams (*Donax variabilis*), and hermit crabs. (See *Beach Profiles* in *Another Angle* on page 9 for more on the residents of these sandy areas.)

Threats: Commercial and residential development on sand dunes is the most obvious human-induced threat to this habitat type. In addition, by developing just landward of dunes, humans have prevented the natural movement of these landforms away from the sea. Trampling of dune vegetation can also lead to dune demise. (Historically, trampling and overgrazing by livestock feeding on dune grass was a big problem.) Because humans have altered dunes to a large degree, extensive sand dune re-vegetation efforts and fencing (to avoid trampling of vegetation) have been undertaken on several popular sandy shores, especially on the Cape Cod National Seashore. Erosion can threaten sand beaches, especially when natural migration of sand is disrupted by jetties, groins, and seawalls. Off-road vehicles threaten sandy beach inhabitants by compacting the sand, making burying and burrowing more difficult. These vehicles can also crush organisms that live just below the surface, and disturb crabs and nesting birds.

Seaward of the intertidal zone (the area between low and high tide), sandy bottoms are generally less threatened by human activities because the organisms that inhabit these dynamic environments have adaptations and behaviors that allow them to handle strong currents, such as efficient swimming skills and a capacity to bury themselves. Nevertheless, trawling and other fishing gear can disrupt sandy bottom communities, especially if the disturbances are frequent. Sand mining for beach nourishment poses a threat to communities inhabiting sandy bottoms, especially if large quantities of sand are continually removed from one area.

ROCK HABITATS

Description: A shoreline drive of the North Shore illustrates why New England is renown for its rocky coast. This rocky substrate also extends beyond what the eye can see to the reaches below the surf. High wave action removes fine-grained sediment from rocky habitats, leaving a range of larger material from solid rock ledges and boulders to cobble and gravel. This size regime strongly influences the composition of the biological community in the rocky habitat. A typical intertidal rock ledge community, for example, includes attached organisms with relatively long life spans (such as brown algae, anemones, barnacles, and mussels), while cobble beaches that are frequently disturbed by wave action tend to host small and ephemeral creatures, such as tiny crustaceans known as amphipods and isopods (e.g., beach hoppers and scuds). Rocky ledges exposed to high wave action have a distinct zonation pattern, with exposure to air and waves, as well as competition, dictating the animals and plants that live in each zone. In areas exposed to heavy waves, the upper reaches, known as the splash zone, are covered with a dark lichen, which is tolerant of salt spray. Below that, barnacles are found in the high intertidal zone, which is submerged during retreating tides. Mussels dominate the mid-intertidal zone, which is exposed as the tide retreats. The low intertidal zone is a dense red mat formed by the algae known as Irish moss (*Chondrus cripsus*) and false Irish moss (*Mastocarpus stellatus*), and is exposed only briefly during low tide. Wave sheltered areas also have a distinctive zonation pattern, but are more heavily dominated by algae than animals.

Rocky subtidal habitats commonly harbor kelp (see the Kelp Beds section above), other fleshy algae, and crustose algae (algae that grow in sheet-like form over rocky surfaces). Mobile inhabitants of the rocky subtidal zone include lobsters, crabs, sea urchins, and a variety of fish species. Some of the organisms found attached to rock ledges and boulders include mussels, anemones, bryozoans, tunicates (sac-like animals with siphons—or seasquirts), and even soft corals. Finally, the biota of subtidal rocky habitats is distinct—many of the species found in these habitat types can only be found attached to rocky substrates.

Importance: The physical structure provided by both the rocks, and the plants and animals that adhere to them, provide valuable habitat for many other organisms, especially small invertebrates and juvenile fish. This structure is important for spawning and for providing protection from predation by larger organisms that cannot access the small spaces between rocks. For example, juvenile Atlantic cod (*Gadus morhua*) are known to congregate around rocky substrates in the subtidal zone. As previously described, kelp in the subtidal zone and the other algae in the intertidal zone (such as rockweed) are vitally important because they provide shelter and structure. Intertidal algae protect snails, mussels, barnacles, and crabs from exposure to sun, wind, rain, and predators when the tide is low. Because of their high productivity, algae in these rocky habitats also serve as important food source. The high abundance of animals that occur in subtidal rocky habitats also support larger species such as diving birds, large fish, lobsters, and humans that target these habitat types while fishing.

Threats: Coastal development can degrade rocky intertidal habitats, especially when nearshore currents are disrupted, so that sediments accumulate on rocky shores. Excessive human visitation can damage and kill rocky shore organisms that are trampled or exposed when rocks are moved. Harvesting of canopy-forming brown algae can have dramatic consequences for organisms that rely on its shelter as a buffer. Rocky intertidal shores have been the subject of scientific scrutiny for decades and recent shifts in species distributions (i.e., declines in cold-tolerant species and increases in the relative abundance of southern species), which are potentially linked to climate change, have been documented. Rock bottom habitats are also susceptible to damage by fishing gear, especially from trawls and anchors.

Caution: Canopy-forming brown algae ahead! Underneath the algae are communities of Dr. Seuss-like inhabitants. Another reason not to step on it: It's slippery and can be slimy!

MUD

Description: Mud flats are areas of unconsolidated fine-grained sediments that are either unvegetated or sparsely vegetated by algae and/or diatoms. Found in wave-sheltered environments that allow fine-grained sediments to settle, mud flats appear relatively featureless except for burrows and small ripples. Most of the organisms that live in the mud are found within a couple of inches of the surface, because below that level, mud typically becomes anoxic (low in oxygen or oxygen depleted). To adjust to these harsh physical conditions, many organisms build and maintain burrows or tubes to access oxygen in the air or water (interestingly, this excavation helps to oxygenate the mud for other species), or have adaptations such as siphons. Because of these successful adaptations, muddy bottoms support high biological diversity—in the Gulf of Maine, muddy bottoms have been estimated to harbor approximately 1,000 species of macroinvertebrates (animals bigger than 0.5 mm) (Watling 1998). The burrowing activities of these inhabitants also release nutrients captured in the sediment to the water column, which can help stimulate growth of marine plants. Like shellfish, many of the organisms that bury themselves in mud are suspension feeders; they obtain food particles from the water, transferring their food energy from the water column to the benthos.

Wavy gravy: Small burrows and ripples are the lone features characteristic of most mud flats.

Importance: Noted for their high density of crustaceans and shellfish, mud flats provide an important food source for large numbers of migrating shorebirds. Wading birds also feed in shallow waters over mud bottoms, and juvenile fish commonly swim from the shallow subtidal zone to feed in mud flats that are submerged at high tide. Under the sea, mud bottoms provide habitat for a variety of benthic organisms—burrowers (clams, crustaceans, and worms) and those that remain above the mud (horseshoe crabs [*Limulus polyphemus*], mud snails [*Ilyanassa obsoleta*], skates, and fish). Undisturbed mud bottoms in the deep subtidal zone are characteristically home to tube-dwelling anemones (*Cerianthis borealis*), tube-dwelling amphipods, brittle stars (e.g. *Ophuria sarsi*), or sea pens (*Pennatula aculeata*). Intertidal mud flats also support recreational and commercial fisheries for soft-shell clams, razor clams (*Siliqua costata*), quahogs, and baitworms (the bloodworm, *Glycera dibanchiata*, and the sandworm, *Nereis virens*). Commercially important species that inhabit subtidal mud bottoms include northern shrimp (*Pandulus borealis*), cancer crabs, the American lobster (*Homarus americanus*), and winter flounder.

Threats: Historically, tidal flats were filled for development, and while this practice no longer occurs, many of these areas are permanently altered. In addition, because they are located in sheltered areas where sediments accumulate, muddy bottoms are especially vulnerable to pollution, as the contaminants deposited are unlikely to be flushed away and because pollutants easily adhere to the small grain size of muddy sediments. Contaminants from the discharge of sewage and stormwater to tidal flats, as well as use of these areas as disposal sites for dredged material, consequently have long-term consequences. Jetties and shoreline stabilization structures alter sediment flow in ways that can result in mud flat erosion or excessive sediment deposition. Bottom-tending fishing gear can stir up sediments and smother sedentary organisms. Introduced species, especially the European green crab, threaten commercially valuable mud flat species. Prior to the introduction of the European green crab, the soft-shell clam was an important fishery resource, but heavy predation by this crab is currently blamed for suppressing soft-shell clam populations.

WATER COLUMN

Description: The open water of Massachusetts can be divided into two zones: the photic zone, which extends from the surface to the depth of sunlight penetration, and the mesopelagic zone, which extends from the bottom of the photic zone to approximately 1,000 meters deep.

another angle

Scale: Habitat Is in the Eye of the Inhabitant

By Anne Donovan, CZM

A sliver of space between two grains of sand. The intestines of a whale. The gill of a fish. A rock worn from centuries of pounding surf. An underwater eelgrass meadow. A salt marsh. An estuary. Thousands of miles of open ocean. Each of these places is a habitat—it's all a matter of scale.

For nematodes (tiny threadlike animals that are often less than a millimeter in length), the scale can be as small as the space between sand and/or mud particles. Nematodes are the most abundant type of animals in coastal and marine sediments, with several million nematodes commonly living within a square yard of mud or sand. In fact, if you took away all of the land and water of the earth, you would still see the outline of all continents and seas in the form of the nematodes left behind.

For whale habitat, the scale can cover thousands of miles of open ocean and coastal waters. Northern right whales (*Eubalaena glacialis*), for example, are known to give birth off the coast of Florida and migrate to areas off of Cape Cod in the late winter/early spring, later making their way up to Canada's Bay of Fundy in search of food. This species is known to roam further still. Amazingly, one right whale known as "Porter" was photographed off Cape Cod in May of 1999—and by September of that year he had wandered more than 8,500 miles to the waters of northern Norway!

Animals and plants themselves also serve as habitats. In fact, certain species of nematodes are whale parasites, which makes whales (or more specifically, whale internal organs) nematode habitat. Right whales are known habitat for barnacles, whale lice (small, parasitic crustaceans), and algae that take up residence on the distinctive white callosities that grow on whales' heads as they age.

Finally, habitat scale for certain species changes throughout their life cycle. For example, juvenile lobsters live for years in a burrow in a section of seafloor real estate that covers about a square foot. As they mature, these creatures can and do travel hundreds of miles to migrate, dramatically expanding their habitat scale in only two years' time.

No matter the scale, these habitats all provide the essential ingredients for the survival of the plants or animals that call them home.

Caution: Wide load! The right whale is one of the biggest water column residents in Massachusetts waters.

another angle

Moving on Up (and Down): Habitats of the Lobster Lifecycle

By Anne Donovan, CZM

For nine months to a year, their habitat is the underside of a female lobster tail. Together with 10,000 to 100,000 of their siblings-to-be, these small, round, pine-green eggs ultimately hatch into pre-larval embryos and are released. After growing into gnat-sized larvae, which look much more like their bug-sized brethren than adult lobsters, they follow the light and swim up through the water column to their new home, generally within a meter of the sea surface.

During this planktonic (or floating) phase of their lifecycle, the lobster larvae that are not voraciously consumed by predators remain adrift for six to eight weeks, molting three times until they ultimately look like little lobsters. These mini-adults then bob around, searching for the right place to settle (literally and figuratively) and start their benthic (or bottom-dwelling) existence. Although they can survive in a variety of habitats, including eelgrass, salt marsh, or even mud (where they dig their own burrows), these choosy crustaceans actively seek out a cobble bottom with all its ready hiding places. The odds of a young lobster making it to the bottom are slim, however, with only one percent surviving to this stage.

For another five-eight years, juvenile lobsters hide and forage for food, seeking out areas with larger hiding places as they grow, such as cobbles, boulders, and other crevices. Ultimately, they reach a size that most predators can no longer tackle. Then they are free to wander the bottom with relative impunity, until they need to molt (i.e., shed their hard external skeleton so they can grow). Before molting, lobsters return to habitats that provide refuge from predators to reduce their vulnerability in this naked (and tasty) soft-shell state. Once their new exoskeleton hardens (a process that takes two weeks to a month) they are again free to roam. Seeking warm waters to improve their growth rates (and the growth of their eggs), adult lobsters commonly summer in shallow, warm, nearshore waters, migrating to deeper waters in the fall and winter when the cool air reduces nearshore water temperatures. Although much about lobster migration is a mystery, the distances covered can be dramatic, with studies finding that some lobsters travel more than 180 miles!

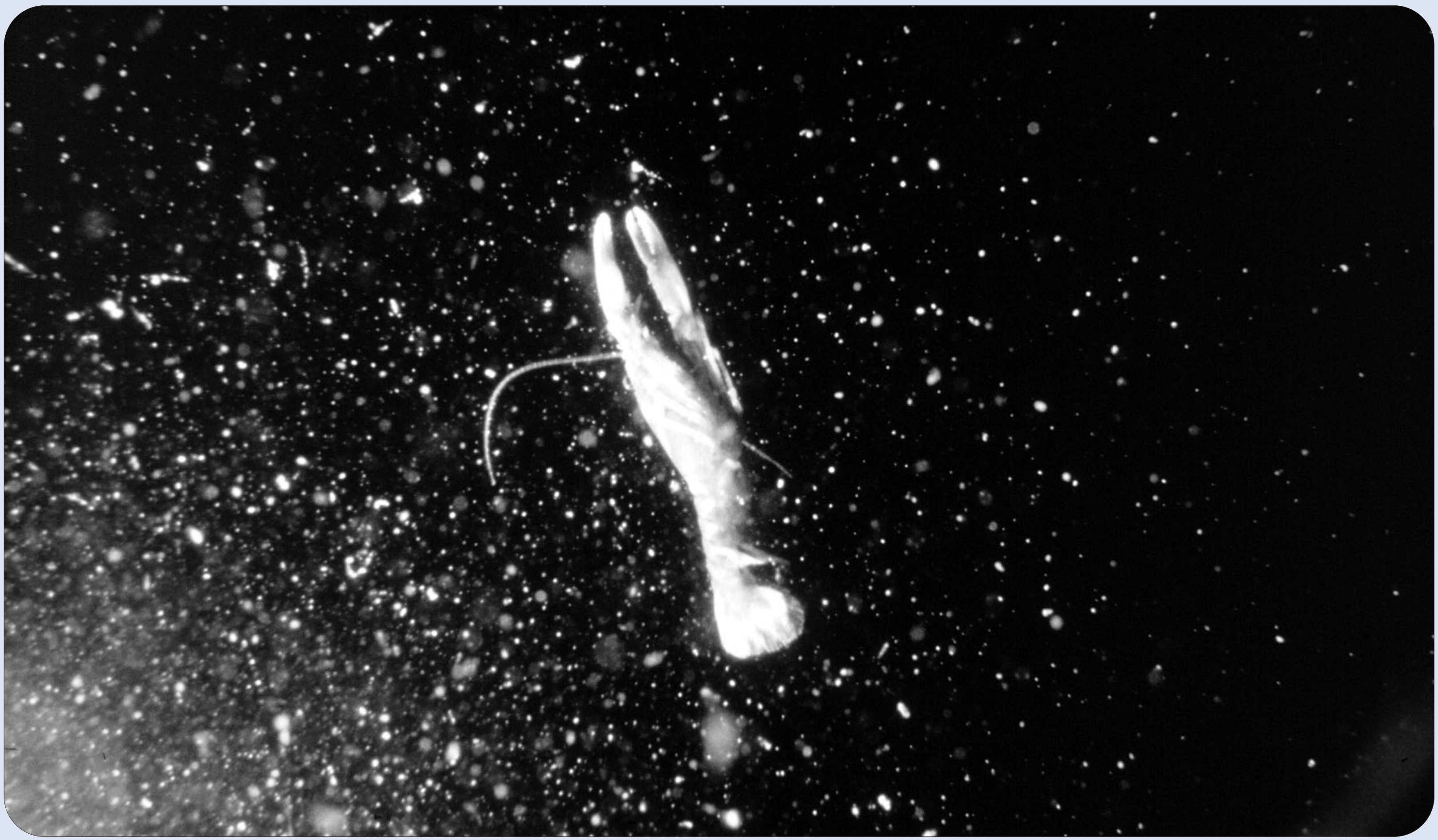
Such is the life of a lobster, moving up, down, and around—occupying different habitat at different life stages and at different times. And lobsters aren't alone. Coastal and marine species from anemones, to barnacles, to cod use different habitats throughout their lifecycles.

It's a bouncing baby boy! Odd, but true: During their mini-adult phase, lobsters bob around in search of cobble bottoms in which to hide from predators.

phytoplankton (tiny plants suspended in the water column) are the primary producers of the photic zone, converting sunlight to energy and supporting all other life in this habitat. In the sunless waters of the mesopelagic zone, inhabitants must either rely on the rain of photic-zone debris or periodically migrate upward to find food. Variations in water temperature, salinity, and density create distinct water masses within the water column and when two water masses collide, fronts are formed creating distinct, if ephemeral, environmental conditions. The water column habitat boasts the widest size range of species—from tiny bacteria and phytoplankton as small as 0.005 mm in diameter to whales tens of meters long. It is also home to many species that swim or float for part or all of their lives. To remain afloat, these plankton use a variety of adaptations. For example, many have long spines or feathery appendages to increase their surface area to volume ratio, while others are composed of gelatinous material that increases their buoyancy. Large gelatinous creatures such as jellies (formerly known as jellyfish) and comb jellies are unique to water column habitats and are consumed by the endangered leatherback sea turtle (*Dermochelys coriacea*).

In some areas, offshore winds blow surface waters away from shore, which results in the upwelling of bottom water to replace the surface water, creating areas of high productivity stimulated by the re-suspension of nutrients. The abundant phytoplankton that grow in these high nutrient conditions feed large quantities of zooplankton (small, floating animals), which feed dense aggregations of small fish such as herring, who in turn feed larger fish, birds, and marine mammals.

Threats: Nonpoint source pollution (runoff from the land that carries nutrients from fertilizer and septic systems; contaminants from car exhaust, pesticides, and numerous other sources; and sediments) is currently the greatest threat to coastal water quality. Harmful algal blooms, or red tides (which are caused by a superabundance of toxin-producing planktonic plants known as dinoflagellates) are also becoming increasingly prominent along the Atlantic coast. Red tides can lead to beach closures and blooms of the dinoflagellate *Alexandrium sp.* can lead to parasitic shellfish poisoning in humans. Overfishing may also strongly influence the species found in the water column. For example, the dramatic increases in the abundance of jellies in coastal waters has been linked to the depletion of fish stocks. Many jellies eat similar food items as fish, and food that was formerly consumed by fish is now available for jellies (Mills 2001). Global climate change, and the associated change in weather and current patterns, pose another threat to water column habitats. Resulting shifts in predominant winds could alter or halt upwelling and changes in the direction or strength of currents could affect the mixing of distinct water masses—both of which could reduce re-suspension of nutrients and lead to diminished productivity in the water column.



Going up? Homarus americanus*—the Latin name for this little lobster—stays afloat in a Gulf of Maine water column.*

ARTIFICIAL HABITATS

Although not always formally considered habitats, piers, docks, shipwrecks, bridge abutments, and other human-made structures in the water and along the shore harbor a diverse mix of organisms. Like rocky outcroppings, these structures can provide surface area for plants and animals to grow, places to hide, and relief from waves and currents—creating habitat for fish and other marine animals. (See *Shipwrecks as Habitat* on page 42 for details.)

While such structures can improve conditions for certain species, they also diminish or destroy habitat value for many native inhabitants. In addition, the assemblages of algae and animals that attach to artificial materials are referred to by marine scientists as fouling communities, and, interestingly, many of the species found here are introduced from other regions. By placing structures in the water, humans may inadvertently be helping introduced species to become established in areas where hard substrates do not naturally occur. For more on the invasive species issue, see *There Goes the Neighborhood: The 2003 Northeast Invasive Species Survey* on page 57.

Finally, many species do make marine and coastal habitats altered by humans home. The habitats within ports and harbors support important populations of fish, shellfish, eelgrass, and other plants and animals. See *Urban Marine Habitats* on page 31 for more on the habitat value of these areas.

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photo by Paul Evans

Got Habitat? Megan Tyrrell: CZM's Habitat Fellow from 2002-2004.

another angle

CZM's Marine Habitat Fellowship

By Anne Donovan

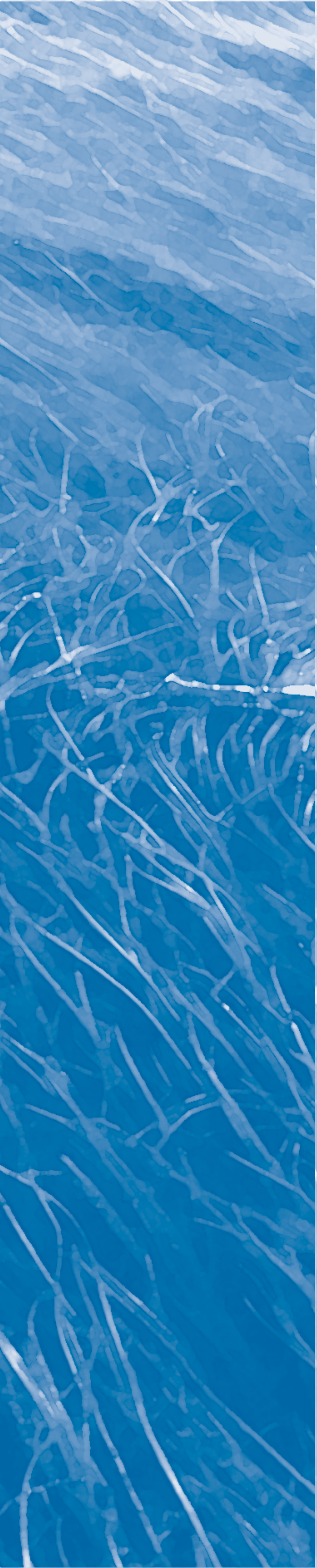
From August 2002 to May 2004, Megan Tyrrell worked as a fellow at CZM, thanks to the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center, which sponsors coastal management fellowships for post-graduate students interested in working on coastal issues at the state level. Megan, CZM's fourth fellow, focused on three major projects with the overall goal of helping to improve marine habitat management in Massachusetts.

1) Data mining to identify information or maps related to marine habitat, including data on sediment grain size, bathymetry, and abundance of benthic invertebrates and fish in selected areas of the state. These data have been added to Massachusetts Ocean Resources Information System (MORIS), a GIS database for marine resource managers.

2) Writing components of a statewide marine habitat management plan, including a benthic habitat mapping strategic plan, and a guide to the marine habitats of the region. The mapping plan, the guide to marine habitats, and other introductory habitat-related documents will be components of the new marine habitat section on CZM's website.

3) Coordinating an interagency marine habitat working group, which includes members of state and federal environmental agencies, fisheries managers, environmental organizations, fishermen, and marine policy experts. The goal of the group is to increase communication among those working on marine habitat related issues within the state and to provide guidance on the creation of the marine habitat management plan.

Eelgrass forms one of the most—if not the most—valuable, shallow marine habitats in Massachusetts coastal waters. Individual plants, clusters of eelgrass, and extensive meadows are found throughout state waters and support creatures ranging in size from microscopic bacteria and larval crabs to foraging bluefish and diving ducks.



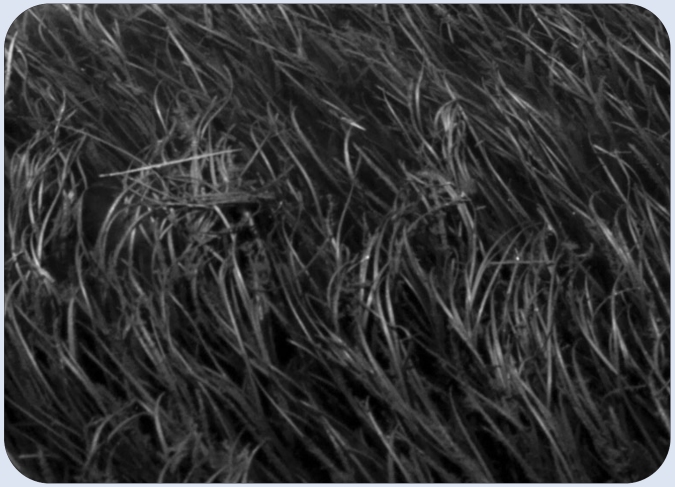
Spotlight on Eelgrass: A Species and Habitat at Risk

By Anthony R. Wilbur, CZM

Charles Darwin, the prominent naturalist who wrote *On the Origin of Species* in 1859, articulated the complexities of natural history, including evolution, species interactions, and community structure. Darwin explained that the abundance of every species is influenced by that of other species, which serve as its food, create its habitat, and/or influence it through a web of relationships. Consequently, the removal of one species or change in its abundance impacts the existence of other species.

Since Darwin's original writings, ecologists have validated the concepts of evolution, species interaction, and coevolution, and have described species that make an unusually strong contribution to community structure or processes as keystone species. Sea otters on the Pacific coast of North America, for example, are a keystone species. Without sea otters and their appetite for sea urchins, the unchecked urchin population can explode. Urchins then heavily graze on kelp, devastating kelp habitat, with impacts that cascade further through this marine community. The keystone species concept can mean different things to different people (as is the case with many ecological concepts)—nevertheless, eelgrass (*Zostera marina*) clearly merits this label. Eelgrass is a prolific primary producer (i.e., converts sunlight to energy), supports diverse and distinct groups of species, provides critical nourishment to herbivores and detritivores (animals that eat partly decomposed organic material), and affects chemical and physical processes in coastal waters. In short, coastal waters with eelgrass are much different than those without it.

The outbreak of wasting disease (caused by a slime mold) that devastated populations of eelgrass throughout waters of North America and Europe in the 1930s emphasized the ecological importance of eelgrass and justified its label as a keystone species. Populations of species dependent on eelgrass, as well as those indirectly associated with eelgrass, were substantially reduced. For example, the eelgrass limpet (*Lottia alveus*) went extinct, Atlantic Brant (*Branta bernicla hrota*) populations nearly vanished from North America, and bay scallop (*Argopecten irradians*) stocks crashed. In addition, current patterns and sediment movement changed because eelgrass no longer anchored seafloor sediments. Eelgrass populations generally recovered from this epidemic. However, because of the environmental consequences of eelgrass degradation of the 1930s, contemporary loss of eelgrass warrants further attention to identify and address the causes of decline.



A single leaf... and a dense meadow of eelgrass.

Geographic Range and Environmental Requirements of Eelgrass

Eelgrass is common to estuarine and marine waters of the north Atlantic and Pacific Oceans. In the northwest Atlantic, eelgrass ranges from New Brunswick to North Carolina, including large areas in Massachusetts. Eelgrass is part of a group of marine plants collectively known as seagrass, which, unlike seaweeds or algae, have a vascular system to carry liquid and nutrients through the plant. There are over 60 species of seagrass worldwide, and two inhabit the coastal waters of Massachusetts—eelgrass and widgeon grass (*Ruppia maritima*).

Eelgrass is the most abundant seagrass species in Massachusetts, forming extensive meadows and patchy beds, and sparsely covering vast coastal areas. Eelgrass is a living habitat, and its location and abundance change through time. (See *Eelgrass: Its Habits and Habitats* on page 23 for details of eelgrass anatomy and habitat requirements.)

Eelgrass grows in a range of environmental conditions, with hydrodynamic factors (such as tidal current speed, water depth, and exposure to waves) determining the character of eelgrass habitat. Waves and currents in high-energy, shallow waters move seafloor sediments, and the eelgrass in these environments grows and migrates with the moving sand, forming linear bands. Sheltered, low-energy embayments, however, can be completely covered by a contiguous eelgrass bed. Light penetration in the water column is also important to eelgrass growth, with eelgrass generally growing denser and deeper in clear water. Bed size and density may influence ecological functions of eelgrass, but whether in a dense meadow or sporadic individual stands, eelgrass is an essential part of coastal ecosystems and its presence indicates the overall environmental quality of coastal waters.

Ecological Functions

Eelgrass forms a complex underwater landscape, with long, narrow leaves floating and swaying in the water column, and tangled roots anchoring the plant to the seafloor and rhizomes connecting one plant to the next. The habitat provided not only depends on whether the eelgrass grows in a dense meadow, patches, or individual strands, but on the species and its life history stage when living in eelgrass habitat. (See *Moving on Up (and Down)* on page 14.)

The bright green leaves of eelgrass are frequently covered by an assemblage of algae and invertebrates whose habitat needs are satisfied by an individual leaf. Bay scallops and mussels are examples of species whose habitat, at least for a time during their lifecycle, is a blade of eelgrass. The size of a pinhead, scallop and mussel larvae settle from the water column onto eelgrass, which provides refuge from predators that are unable to swim or climb eelgrass blades, and a stable supply of food flowing by the leaves. When these bivalves grow, they let go of the blade and move to the seafloor.

Fishes and crabs, on the other hand, are associated with eelgrass habitat on a broader scale. The community of fishes and crabs inhabiting eelgrass is dramatically different from areas devoid of the plant, with eelgrass habitat supporting a higher diversity and abundance of life. Certain fishes, such as pipefish (*Syngnathus fuscus*), inhabit eelgrass habitat for the majority of their lives. Other fish and crab species, while capable of surviving in other habitats, use eelgrass during parts of their life cycle. Atlantic cod (*Gadus morhua*), tomcod (*Microgadus tomcod*), cunner (*Tautogolabrus adspersus*), rock crab (*Cancer irroratus*), and American lobster (*Homarus americanus*), for example, move around the leaves and stems and scurry along the bottom among the roots, using the eelgrass for protection from predation and to ambush prey. These mobile species and many others also use eelgrass as nursery habitat. Many benthic invertebrates live in and around the root system of eelgrass. Newly settled lobster burrow between the roots, and a diversity of lesser-known animals from worms to snails inhabit the sediments among the roots and rhizomes. Not only do these creatures find refuge and prey in eelgrass beds, many creatures directly forage on leaves and the accumulated partly decomposed leaves (detritus).

Species also frequently live around, not necessarily within, eelgrass beds, periodically moving into beds for protection or to feed. Winter flounder (*Pseudopleuronectes americanus*), for example, are observed in bare areas between eelgrass patches. Above the surface, waterfowl peer through the water looking for a meal of eelgrass or the creatures harbored there. The biological community associated with eelgrass is well studied in temperate waters, but the ecology of eelgrass in southern New England and the Gulf of Maine is not completely understood and more associated species and species interactions are sure to be discovered in the future.

Eelgrass leaves naturally break away from the root system every autumn, similar to trees losing their leaves. These leaves accumulate on the shore and provide important ecological services. Piles of beach wrack are found all along the coast and may be the only aspect of the eelgrass lifecycle that beachcombers notice. The beach wrack, predominately composed of eelgrass in many areas, shelters abundant insect and amphipod communities that are critical prey for shorebirds, including the threatened Piping Plover (*Charadrius melodus*). Not only is wrack important foraging habitat, it captures and holds sand and other sediment, helping to reduce beach erosion. Most leaves that become detached do not reach the shore, however, and sink to the seafloor, creating a detritus soup that is fundamental to the ocean's food web and is used by deposit feeders and exported to other biological communities.

Eelgrass also contributes to chemical and physical processes of coastal waters. Eelgrass produces oxygen (through photosynthesis), absorbs nutrients and pollutants, and improves water quality. Leaves slow water movement and roots stabilize sediments, promoting sediment deposition and minimizing shoreline erosion. Overall, the presence and condition of eelgrass is a strong indication of the environmental quality of coastal waters.

Threats to Eelgrass Habitat

Eelgrass is influenced by both natural and anthropogenic factors. Digging, grazing, choppy seas, ice scour, and disease all impact the plant. In extreme cases, eelgrass can disappear after a harsh winter with ice scour and turbulent waters. However, eelgrass is resilient and typically recovers from natural disturbances. The most dramatic lasting changes to eelgrass habitat are caused by humans.

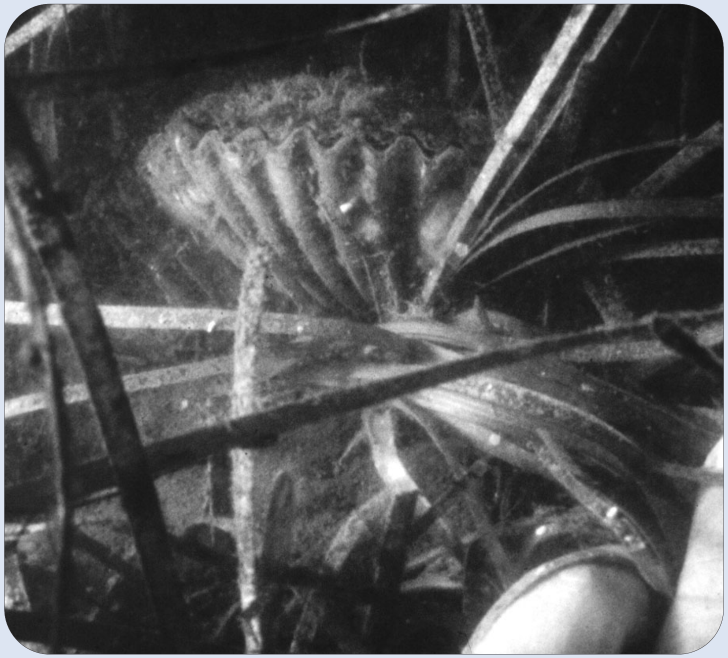
Physical disturbances, such scarring from boat propellers, anchors, and mooring chains, and activities that alter intertidal and subtidal environments (e.g., dredging, shellfishing, and aquaculture activities) can degrade and reduce eelgrass populations. Poor water quality is also a significant threat, since eelgrass has the highest light requirement of any marine plant. Minor changes in light availability, which is synonymous with water clarity, substantially influence the quality of eelgrass habitat. Light available to eelgrass is dictated by phytoplankton abundance, algal abundance and cover (e.g., epiphytic algae and benthic algae), and sediment suspension (turbidity).


Mooring "donut holes"as seen from above.

photo courtesy of MassGIS

There are many threats to eelgrass; the photo above illustrates impacts caused by moorings. (Dark areas in photo denote eelgrass beds.)

Eutrophication (i.e., nutrient over-enrichment), which is typically linked to development in coastal watersheds and the associated runoff from groundwater, lawns, parking lots, and septic systems, promotes growth of algal epiphytes (algae species that grow on other plants) and phytoplankton (microscopic plants in the water column). Both of these plant types absorb light in the water column and decrease its availability to eelgrass. Low water clarity and high nutrient levels stimulate the proliferation of benthic and drift algae. These algae require less light and can smother or out-compete eelgrass for space. Other pollutants degrade and kill eelgrass, such as herbicides used on lawns and larger landscapes (e.g., golf courses).



Home, Sweet Eelgrass. Scallops enjoy protection nestled within Casa Del Zostera marina.

Currently, eelgrass loss in Massachusetts is more widespread on southern Cape Cod and Buzzards Bay than in the waters to the north. Although historic losses in Massachusetts Bay were dramatic and contemporary disruption of eelgrass habitat remains, existing beds in waters of western Massachusetts Bays generally appear stable. The watershed and coastal development that occurred in the past several decades on Cape Cod and in southeastern Massachusetts has resulted in increased nitrogen loads and extensive eelgrass habitat degradation. In addition, sea level rise and global warming are also considerable future threats to eelgrass. With rising seas and increasing water temperature, seagrass habitats, including eelgrass, may be drastically diminished along the Massachusetts coast and throughout coastal waters of the world.

Eelgrass Management

The Massachusetts Department of Environmental Protection (DEP) maps the distribution of eelgrass on a three-year cycle and several government and academic groups are developing monitoring programs to assess eelgrass habitat quality. These projects are valuable components of eelgrass management, but regulation to specifically conserve and restore eelgrass habitat is also important. Similar to tropical coral reefs, there is global concern about the loss of seagrass habitat. A key priority in any conservation plan is to identify the species or groups of species (communities) that contribute critical ecological functions, and to develop measures to protect those resources. Seagrass receives special consideration by the federal Clean Water Act and Rivers and Harbors Act and Massachusetts Wetlands Protection Act during permit review, but only when proposed projects may alter existing eelgrass habitat. Australia and some parts of the United States, particularly states surrounding the Chesapeake Bay, are actively conserving and restoring existing, historic, and potential seagrass habitat. These programs can guide the development of a Massachusetts seagrass conservation plan designed to protect and restore this keystone species.

FOR FURTHER INFORMATION

Massachusetts Department of Environmental Protection - http://www.state.ma.us/mgis/eelgrass.htm.

Chesapeake Bay Program - http://www.chesapeakebay.net/.

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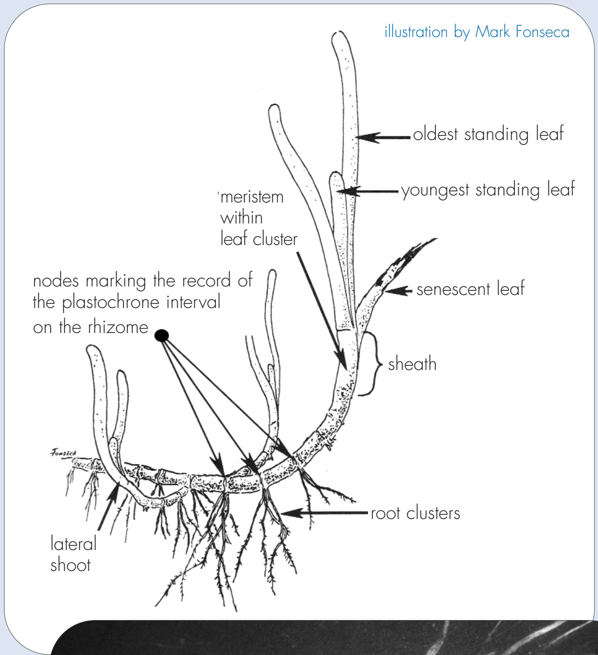
Eelgrass Schematic

Thayer, G.W., W.J. Kenworthy and M.S. Fonseca. 1984. *The ecology of eelgrass meadows of the Atlantic coast: a community profile*. US Fish and Wildlife Service FWS/OBS-84/02. 147pp.



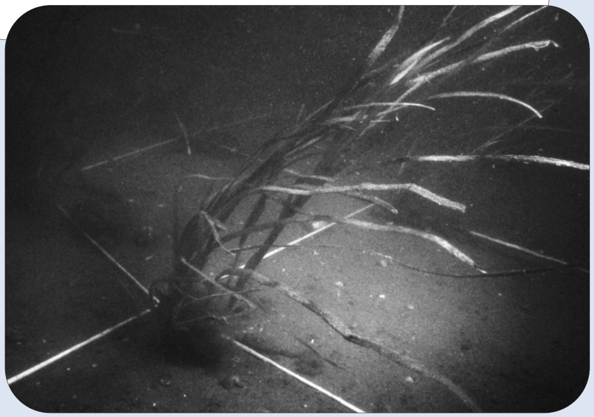


Diagram of eelgrass (top), and eelgrass "in action."

Eelgrass: Its Habits and Habitats

By Anthony R. Wilbur

As shown on the left, the anatomy of an eelgrass (*Zostera marina*) plant includes leaves, rhizomes (runners that connect one plant to the next), and roots. Eelgrass, a flowering plant with all life cycles occurring underwater, grows in intertidal and subtidal zones and tolerates wide ranges in salinity and temperature. A variety of seafloor sediments, current and tidal regimes, and shoreline types support eelgrass growth. For instance, eelgrass can grow in high-energy environments among cobble substrates by anchoring its roots in finer sediments deposited between the cobbles. Eelgrass is, however, predominantly found in calm, marine embayments and soft sediments (mud and sand). Light penetration through the water column dictates the depth of eelgrass growth (i.e., clearer water supports deeper growth), and there are areas in Massachusetts and Cape Cod Bay where eelgrass was observed growing as deep as 40 feet.

Eelgrass forms one of the most—if not **the** most—valuable, shallow marine habitats in Massachusetts coastal waters. Individual plants, clusters of eelgrass, and extensive meadows are found throughout state waters and support creatures ranging in size from microscopic bacteria and larval crabs to foraging bluefish and diving ducks. It is widely accepted that animals require habitat, but plants also need specific habitat conditions to survive. Decreasing water quality, sediment contamination, and seafloor disturbance are altering environmental features necessary for eelgrass growth and survival, with potentially significant consequences. The loss of eelgrass habitat transforms embayments from complex, flourishing landscapes to homogenous seafloor habitats that do not provide equivalent ecological services.

Tide Pools—Depths Observable from Dry Land

By Dr. Robert Buchsbaum, Massachusetts Audubon Society

TIDE POOLS, AS THEIR NAME IMPLIES, are the pools of seawater that remain in the intertidal zone (i.e., the area between high and low tide) when the tide has receded. They are a common feature of rocky shorelines because the nooks between boulders and the cracks and depressions in bedrock effectively trap and hold water. In these dynamic and constantly changing pockets of ocean, a host of specially adapted plants and animals make a home.

To the marine biologist, tide pools are mini-ecosystems where the processes of competition, herbivory, predation, and biological invasions can be well studied within the context of a harsh, wave battered environment. To a family on vacation, they are fascinating windows on ocean life. Unless you are willing to try snorkeling or scuba diving, there is no better place to observe marine critters going about their business in a natural environment. For those in search of a meal (once they obtain the appropriate permits, of course), tide pools contain edible shellfish and seaweeds, as well as juveniles of many other tasty species. To the artists, the intertidal rock pools of New England are a constantly changing palette of different colors and textures: fronds of olive, brown, and purple seaweeds waving in the water; crusts of bright red, pink, and brown seaweeds looking like paint splashes on the rocks; green, red, and white sponges; spiky sea urchins; and chalky barnacles.

The interplay of physical factors and biological interactions determine the characteristics of individual tide pools. The location of the pool in relation to low and high tides is a key physical factor, determining the amount of time a tide pool remains submerged by ocean waters or exposed to air during the daily tidal cycle. This exposure time affects the stability of environmental conditions and consequently the types of organisms that can survive. Farthest from the sea are the high tide pools, some of which are flooded only during extreme high tides while others are covered with ocean water daily, but for only an hour or two each day. During the heat of a summer day, direct sunlight elevates temperatures in high tide pools to extreme levels. If it rains when the tide is out, salinities in these high tide pools may decline rapidly. These extreme fluctuations mean that to survive in a high tide pool, organisms must be highly tolerant of temperature and salinity fluctuations. As a result, high tide pools tend to be lower in species diversity than those closer to the sea. Many are dominated by green algae that are tolerant of temperature and salinity extremes and thrive where conditions are too unstable for the animals that eat them.

At the other end of the spectrum are the low tide pools, which are directly connected to the ocean except for a few hours around the time of low tide, or for those at the extreme low limit, are exposed to air only on a few days each month during the lowest tides. Tide pool aficionados are keenly attuned to the lunar cycle of spring (extreme) and neap (weak) tides so they know when they can reach some low tide pools that are only accessible during spring tides.

Because they are covered with water most of the time, low tide pools are relatively stable compared to those at mid and high elevations. Low tide pools closely resemble the adjacent shallow subtidal waters and, all else being equal, contain the greatest diversity of organisms. This is the place you are most likely to find the superstars of intertidal life, such as seastars, brittle stars, sea cucumbers, anemones, nudibranchs, sponges, and kelps. The relatively stable physical conditions allow biological interactions to play a more prominent role in determining who lives in low tide pools than in the high tide pools. As an example, sea urchins, which cannot survive the changeable physical conditions in high tide pools, are voracious herbivores in low tide pools, often consuming all seaweeds except for those that are hard inedible crusts. Thus smaller marine creatures that depend on upright seaweeds for hiding from predators are out of luck when sea urchins are abundant.

Size and depth are other key factors that influence tide pool life. A particularly large, deep pool at mid to high tide could harbor creatures that would normally be found only in a low tide pool, since the larger the volume of water, the less significant the temperature and salinity fluctuations. Tide pools with a complex structure, such as a bottom covered by jagged rocks, tend to harbor more organisms than pools with smooth bottoms. Complexity provides more surface area for seaweeds and for sessile, filter-feeding animals like mussels and sea squirts to attach. It also provides hiding places from predation. Another major factor is wave exposure. Limpets, chitons, and barnacles are well adapted to handle harsh waves, whereas periwinkle snails are not.

Because of their small size and definite boundaries, tide pools of Massachusetts have been wonderful outdoor laboratories to study ecological interactions between organisms. Ecologists can, for example, remove one component of the biological community and then examine the responses of other organisms. In the 1970s, Jane Lubchenco, a well-known marine ecologist who was then a graduate student at Harvard, found that when she removed the dominant herbivorous snail, the European periwinkle (*Littorina littorea*), from mid-tide pools in Nahant, the pools became overgrown with a monoculture of sea lettuce and other green algae. The pools without snails contained fewer species of seaweeds and sessile (stationary) animals because the competitively dominant green algae excluded other species. By preferentially feeding upon green algae, the snails gave other algae, such as the slow growing pink crusts, a better chance to grow. Thus, more snails equal more diversity in the tide pool. Young snails, however, were preyed upon by European green crabs (*Carcinus maenas*), thus the crabs could prevent recruitment of new snails to the tide pools and foster the dominance by green algae. Gulls, which feed on the crabs, provide another level of control on the community.

The tide pools of Massachusetts are not the same today as when colonists first arrived from Europe due to the invasion by non-native species. The aforementioned green crab is a European native that arrived on the East Coast of the United States in the 1800s. The Asian shore crab (*Hemigrapsus sanguineus*) has been in the Bay State for less than 10 years. Both are voracious predators and conceivably have had a host of impacts on tide pool ecology. The European periwinkle, so abundant in our tide pools today, showed up in New England only after 1850. Recent genetic evidence suggests that this may be a range expansion by a species native to North America that survived in an unglaciated part of the northeastern Canada during the last ice age rather than an invasion by a European snail. Dumont's red weed (*Dumontia incrassate*), a common seaweed in mid-tide pools in early summer, came from Europe and was unknown in New England before 1900.

Tide pools provide one of the most accessible and enjoyable ways to learn about the natural history of coastal habitats. Show a child and a parent a tide pool, and without any particular enticement, they will start looking to see what treasures are there. The Massachusetts Audubon Society and Salem Sound Coastwatch have taken advantage of the public's natural affinity for tide pools by recruiting volunteers to monitor them so that we can learn about invasives and other possible long-term changes. To become a volunteer tidepool monitor, see http://www.salemsound.org/chimp.htm.

Tide pools: Constantly changing pockets of ocean.

Deep Sea-Corals:

Ancient Forests in the Depths

By Maura Christhilf, CZM

FROM THE STEEP-SLOPED BOTTOM, bright orange and pink arms reach up 10 feet into ocean currents. Wide fans of red stretch 20 feet across and seven feet high. Fish dart to and fro between the branches and their rocky anchors. These colorful structures are their shelter and their food source—a coral habitat—but this is not a scene off some tropical island. Instead, these coral forests thrive in this always cold, dark water near the continental shelf off the Massachusetts coast.

Yes Virginia, there are corals in the north Atlantic! These are found off the Commonwealth's coast in the deep depths.

Unlike their shallow tropical cousins, deep-sea corals are found hundreds of feet to more than a mile below the ocean's surface. Often found on the edges of continental shelves or on underwater islands called seamounts, these creatures gain their sustenance by feeding on the microscopic animals floating around them. Unlike hard, reef-building or stony corals found in warm waters, these corals are the soft type whose feathery plumes sway with the ocean current. They grow very slowly, usually no more than an inch per year depending on the variety, but can live to be hundreds, even thousands of years old. Anchored to outcroppings of rock on the ocean floor, they form habitats that provide homes and food for other sea life such as sponges, sea anemones, sea squirts, and fish.

Deep-sea corals are thought to make up the majority of all known coral species. Yet because of their remote habitat, it is generally believed that there are many more species that have yet to be discovered. After pulling up large sections of coral while fishing, fisherman often speculated on what they thought were the great, petrified tree forests hidden in the depths below. Only now, as manned and unmanned submersibles explore previously unknown coral habitats, can these legendary forests be examined. Of the known varieties, 15-20 species of deep-sea corals have been found in the Gulf of Maine. Two of the more prolific types that have been identified are *Paragorgia arborea*, nicknamed "bubblegum tree" for its orangey-pink color and lumpy texture, and *Primnoa resedaeformis*, known as "sea corn" or "red trees" for the kernel-like bumps that cover its branches when dried. Both corals have been known to form wide and high branches that extend out many feet from their origin.

Corals are large contributors to the boon humankind reaps from the ocean. Pharmaceutical scientists and manufacturers look to the sea, recruiting marine life (including deep-sea corals and some of the other animal species that call this habitat home) to create some of the drugs now made with ingredients derived from nature. New knowledge about these formerly elusive corals may lead to development of products spanning from dietary supplements to cosmetics.

Scientists are also hoping that large coral skeletons can provide clues regarding changes in the ocean environment over time. Just as the growth rings of a tree serve as a permanent record of drought, pestilence, and other habitat changes, coral growth layers may give insights into variations in water temperature and chemical composition, and the effects of sediment and pollution on coral growth. Perhaps by understanding past events, scientists will be able to predict future changes.

The deep-sea oases formed by corals are also a Mecca for a variety of fish and shellfish species. Coral thickets provide a rest from ocean currents, cover for young fish, and an ideal area for spawning. Many species such as Acadian redfish (*Sebastes faciatus*), cusk (*Bromse bromse*), monkfish (*Lophius americanus*), black sea bass (*Centropristis striata*), and shrimp have been observed congregating among these coral havens—and their numbers have not gone unnoticed. Commercial fishermen have enjoyed increased catches of these fish in areas known to be coral-rich environments. Unfortunately, this knowledge, coupled with advanced fishing technology and techniques, threatens many pristine and epic deep-sea coral forests.

Fishermen once avoided these jagged formations with their long skeletal branches that snag lines and ruin nets, creating costly equipment losses. New developments in trawling, however, allow nets to traverse the bottom without getting hung up. Bottom trawling can be extremely destructive to corals when trawl doors weighing several tons inadvertently crush or injure coral formations. Global Positioning Systems and fish finders also better help fishermen locate their quarry, sometimes within these vulnerable deep-sea coral habitats. Once impacted, recovery is difficult. Because of their slow growth, coral forests may take hundreds of years to rebuild, and recent studies are finding that some coral colonies may cease growing altogether after being damaged.

In recognition of the potential importance and vulnerability of the deep-sea coral habitat, scientists worldwide are rushing to locate and identify coral forests in an effort to further understand their biology and contributions to the marine environment. In the past three years, deep-sea coral conferences have been held from Ireland to Hawaii, bringing together experts interested in dispersing knowledge and promoting potential conservation efforts. Hopefully, these efforts will lead to balanced management approaches that protect these beautiful and diverse deep-sea coral reefs that nature has taken thousands of years to create.

Seamounts, the Habitat of Deep Sea Corals

By Maura Christhilf, CZM

Much like the Hawaiian islands, seamounts, or underwater islands, form over hotspots in the earth's crust. Lava erupts through cracks and over thousands of years builds to a rocky underwater mountain perfect for corals, sponges, and sea anemones to colonize. Many of these stationary inhabitants rely on ocean currents flowing over the seamount to provide the nutrients they need to live. These same currents carry reproductive components and larvae to new spots, assuring continuation of the species that are often endemic, or specific only to the area where they are found. Fish hide, rest, and reproduce among the corals and sponges, and larger fish come to feed on them. Seamounts, like the substantial chain found off the Massachusetts coast, consequently provide a unique habitat in the vast depths of the ocean.

CZScience

Mapping the Geology of the Seafloor

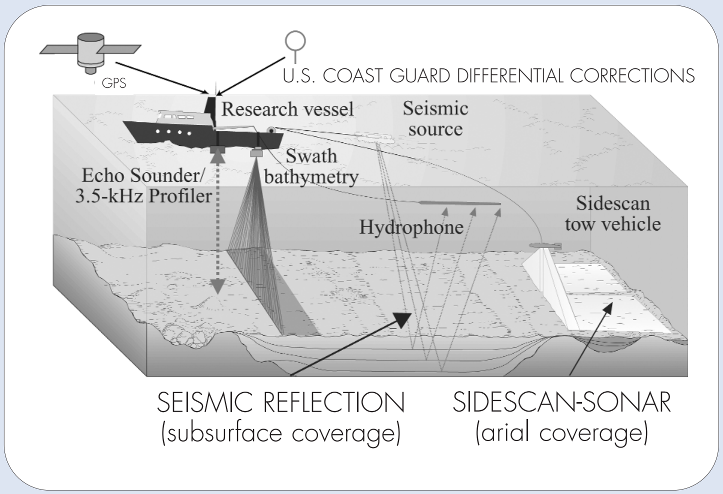
By Brian Andrews and Bradford Butman, U.S. Geological Survey

The bottom of the ocean is mapped for a number of environmental, research, and commercial applications, such as navigational charting, oil and gas exploration, and marine and coastal resource management. Monitoring the health of the seafloor has recently attracted more attention due to increased demand for this information from fishing, the oil and gas industry, and other commercial interests. A suite of acoustic and visual tools is used to study the geology of the seabed and sub-surface layers. These tools can define the geologic framework (seabed morphology [the shape and general landform of the seafloor], surficial sediment distribution, and underlying geologic structure) of a particular region, which then forms the base for further studies of the seabed, such as on sediment transport, coastal erosion, and benthic habitats.

Geologic Seafloor Mapping Methods

The primary tools used for seafloor mapping are acoustic (or sonar) systems that transmit and receive an acoustic pulse from a device called a transducer, which is mounted on a survey vessel or towed in a separate tow-vehicle (called, appropriately, the "fish"). Sonar systems map a narrow strip or swath of the seafloor perpendicular to the ship's track. Surveys are designed so that multiple adjacent lines can yield 100 percent sonar coverage of the seafloor. The travel time of the acoustic pulse (from the transducer to the seafloor, and back) and the strength of the return signals are used to measure the depth to the seafloor (bathymetry), depth to sub-surface sediment layers (sub-bottom), and the "reflectance" of the seafloor (intensity of backscattered energy) (Figure 1). Sonar systems operate at various frequencies. The purpose of the survey and depth of the study area determine the type of sonar system used for a seafloor mapping investigation. Generally, most sonar systems used in mapping areas in the continental shelf operate in the 30-500 kHz range. Lower frequency sonars are typically used in deep water applications because there is less absorption of the sonar pulse, so the lower frequency acoustic pulse can travel greater distances. Sub-bottom information is acquired using very low frequency (Hz-12kHz) systems that are able to penetrate the seafloor and locate underlying geologic structures.

Optical techniques, such as photography and video, are used to collect data about the surface of the seafloor and to "ground truth" the sonar data by correlating the photographic images with features in the sonar record. For example, one kind of seafloor mapping system, a sidescan-sonar, measures the strength of the reflected acoustic signal. This reflected signal, known as backscatter intensity, allows geologists to infer the composition (or grain size) of the surface sediments (such as cobble, sand, gravel, or bedrock). Photography and seafloor sediment samples are used to relate backscatter intensity to a physical sample of the seafloor. In general, low backscatter intensity is measured in fine-grained areas, and stronger backscatter intensity in regions of rock or coarse-grained sediments. Within a map of backscatter intensity, dark tones usually represent areas of low



schematic courtesy of MassGIS

Figure 1. Marine data collection systems used in seafloor mapping. Differential global positioning systems (DGPS) provide navigation, and locate both the survey vessel and the collected data. A single-beam echo sounder measures water depth and provides a continuous profile of the seafloor directly below the vessel. A 3.5-kHz sub-bottom profiler sends and receives sound pulses that penetrate 5-10 meters into the seafloor. An interferometric bathymetric swath sonar system measures water depth and the intensity of sound reflected from the seafloor; the hull-mounted transducer sends out a fan of sound, which is reflected from the seafloor and received at the transducer. In high-resolution seismic-reflection profiling, a towed sound source transmits acoustic pulses that are reflected off the seafloor and layers beneath. Towed hydrophones (shown left) or hydrophones built into the sound source receive the returned signal. Sidescan-sonar systems map the intensity of the sound reflected from the seafloor on either side of the towed vehicle that emits a fan of sound. The reflections provide an image of the seafloor and information on sediment types. (Source: USGS)

backscatter intensity (generally fine-grained sediments), and lighter tones represent areas of high backscatter intensity (generally coarse-grained sediments) (Figure 2). The combination of remote sensing, or sonar mapping, and direct sampling (photography, sediment samples) of the seafloor allows geologists to define the sediments and underlying structure of the seafloor.

Analysis and Visualization

While the tools and techniques for acquiring bathymetry and backscatter intensity are well established, those for extracting quantitative information from these data to define the geology and seafloor habitat are continually developing. Interpretation of marine remotely sensed data is challenging due to factors that affect the data while it is being acquired (e.g., wind, ship noise, sea state) and the historically subjective nature of visual interpretation. Visual analysis of sonar data can reveal areas of similar characteristics. However, a rigorous quantitative analysis using photographs or surface sediment grabs to examine biological characteristics of the seafloor can yield more repeatable results that can then be used to identify and define areas of unique geologic and benthic characteristics. All of this information can then be processed using a geographic information system (GIS) to generate habitat maps of the seafloor. Data collected on the seafloor geology (seabed morphology, sediment distribution, and underlying structure) and biology (e.g., species density and community structure) are entered into a GIS that facilitates further analysis and interpretation (Figure 3). Mapping seafloor habitats is an evolving process, but identifying distinct geological areas that provide the substrate for animal populations is a fundamental component. As methods are developed to identify biological habitats, the maps of surficial geology will prove invaluable.

Seafloor Mapping Projects in Massachusetts

The U.S. Geological Survey (USGS), in cooperation with the Massachusetts Office of Coastal Zone Management and the National Oceanic and Atmospheric Administration (NOAA), began a three-year project designed to collect geologic seafloor data within the coastal waters along the North Shore of Massachusetts and Boston Harbor. This project complements existing seafloor data collected by USGS and NOAA within the Stellwagen Bank National Marine Sanctuary, and western Massachusetts Bay from 1994-2000. These data and resulting interpretations will be applied to further marine research and coastal and marine resource management projects, by federal, state, private sector, and academic organizations. These investigations will facilitate comprehensive study and monitoring of the seafloor environment.

To learn more about this project, visit the project website at http://woodshole.er.usgs.gov/project-pages/coastal_mass/index.htm.

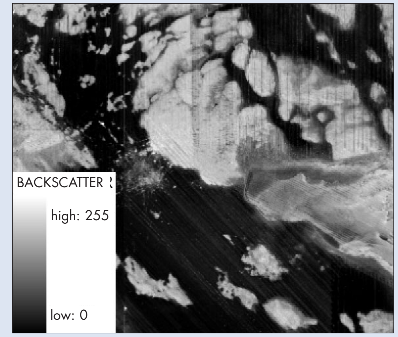


Figure 2. Sidescan-sonar mosaic from Stellwagen Bank National Marine Sanctuary. Areas of low backscatter intensity (soft sediments) are shown as dark tones and areas of high backscatter intensity (rough surfaces such as cobble and rock) are shown as lighter tones.

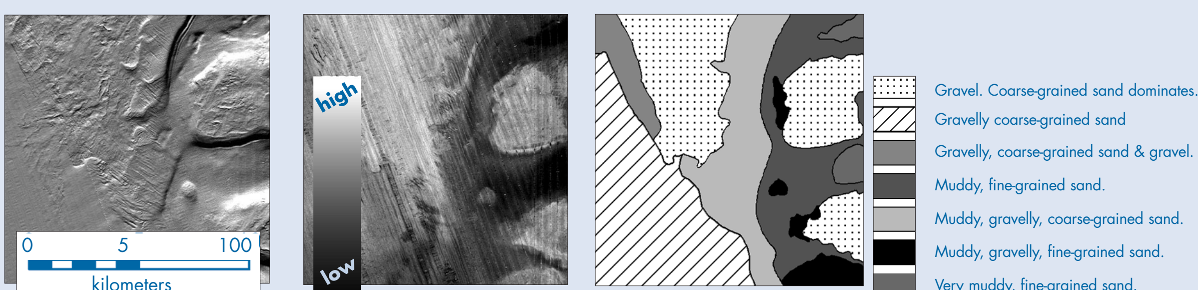
Additional Resources:

USGS National Geologic Studies of Benthic Habitats, Northeastern United States
http://woodshole.er.usgs.gov/project-pages/stellwagen/

High-Resolution Geologic Mapping of the Sea Floor Offshore of Massachusetts (USGS)
http://woodshole.er.usgs.gov/project-pages/coastal_mass/index.htm

Sea-Floor Mapping Technology (USGS)
http://woodshole.er.usgs.gov/operations/sfmapping/index.html

Gulf of Maine Mapping Initiative
http://gulfofmaine.org/council/publications/gommifactsheet2002.pdf



schematics courtesy of MassGIS

Figure 3. Far left: Color sun-illuminated bathymetry. Depths are vertically exaggerated five times. Illumination source is from the northwest at 45 degrees altitude. Middle: Sidescan-sonar mosaic of the same area illustrating areas of low backscatter (dark) and areas of high backscatter (white). Right: Same area showing interpreted bottom types from analysis of depth, backscatter, bottom photography, and sediment sampling data.

Urban Marine Habitats

Urban Marine Habitats—*Spotlight on Gloucester Harbor*

By Dr. Todd Callaghan and Anthony R. Wilbur, CZM

Amidst an undulating mass of eelgrass, a snail moves along a single green strand, gently grazing on a thin slime of algae. Beneath the thicket of eelgrass blades, a juvenile lobster cautiously pushes its way out of its sandy burrow to forage on small worms and clams. Suddenly, the shadow of what appears to be a large fish passes over the lobster. With a kick of its tail, it retreats to shelter. The shadow moves over and abruptly changes direction. Several hundred small mirrors turn at the same moment in a silvery flash. It isn't one fish, but a school of juvenile menhaden feeding on a patch of nutritious plankton. In an instant, two more shadows pass over the lobster's burrow and it wisely stays inside. A pair of hungry striped bass propel themselves toward the trailing edge of the school of menhaden, isolating a few stragglers and quickly swallowing them whole. Remnants from the feeding frenzy fall lightly to the bottom. The juvenile lobster hurries out of its burrow and secures an easy meal.

Is this a scene from the Discovery Channel? Feeding time at the New England Aquarium? No, this is an example of some of the ecological interactions that occur beneath the surface in any one of the Bay State's many busy harbors. Televised nature programs have made us aware of the diverse and colorful life swimming, burrowing, eating, and being eaten in remote locations across the globe, but how many of us know and appreciate the diversity and tenacity of aquatic life right here in local ports?

Many commercial ports along the Massachusetts coast (including Gloucester, Salem, Boston, Plymouth, Provincetown, Hyannis, Nantucket, New Bedford, and Fall River) have been active for centuries. Together these ports provide the Commonwealth with waterways and dockage for fishing fleets, tankers, container ships, recreational boats, and ferries. While many of these man-made additions to natural harbors and their associated environmental impacts are obvious, what is less known is that these ports contain viable habitats (albeit fragmented, sometimes polluted, and frequently disturbed) that continue to provide ecological value to a number of species. The key to continued aquatic diversity in high human impact areas such as ports is the persistence of a variety of habitat types in which organisms can forage, seek shelter, and reproduce.

Baby lobster gets comfortable nestling within the cobble rubble.

This article focuses on specific habitats in Gloucester Harbor, which supports nearly 3,000 full-time and 800 part-time employees and generates $720 million in sales, largely in the commercial fishing and frozen seafood sectors. Dramatic changes to Gloucester's inner harbor resulted from the filling and armoring the entire inner harbor, especially around Five Pound Island with the creation of the State Pier. While these changes had unavoidable environmental impacts, the port of Gloucester continues to harbor several habitat types that support a variety of species.

Seafloor

Even with dozens of recreational and commercial boats passing through the harbor every day, the mud, sand, and rock of the seafloor, and the waters above continue to provide habitat for numerous organisms. For example, trawl surveys in 1998-1999 revealed that some commonly known fish species, such as winter flounder (*Pseudopleuronectes americanus*), skates, and Atlantic cod (*Gadus morhua*), were the fish species of greatest abundance on the Gloucester Harbor seafloor throughout the year. Some other well-known species such as hake (*Urophycis chuss* and *U. tenuis*), pollock (*Pollachius virens*), cunner (*Tautogolabrus adspersus*), windowpane (*Scophthalmus aquosus*), and butterfish (*Peprilus triacanthus*) were also present, but in lower numbers. The survey also turned up some fish that sound more like they belong in a science fiction novel than on a dinner plate: lumpfish (*Cyclopterus lumpus*), longhorn sculpin (*Myoxocephalus octodecemspinosus*), rock gunnel (*Pholis gunnellus*), grubby (*Myoxocephalus aenaeus*), snailfish (*Liparis spp.*), radiated shanny (*Ulvaria subbifurcata*), ocean pout (*Macrozoarces americanus*), sea raven (*Hemitripterus americanus*), and pipefish (*Syngnathus fuscus*). Interestingly, while skate and winter flounder dominated the catch from June to October (60-80 percent of total abundance), winter flounder enjoyed the number one spot without rival from November to January (30-80 percent of total abundance) and then was surpassed by cod from March to May (20-50 percent of total abundance).

The appearance and disappearance of species in the survey record is at least in part determined by the different habitat needs of those species. Species that prefer cool water for spawning or foraging, (e.g., winter flounder and cod) move into Gloucester Harbor during the cooler months, while others like skate find their niche in the harbor in the warmer months. In addition to this temporal variability, these species also have spatial preferences. According to a 2001 survey, 63 percent of the Gloucester Harbor seafloor is silt (soft mud), while the remainder is a combination of silt, sand, and hard bottom. The silty seafloor attracts juvenile and adult fish of many species that feed upon the abundance of polychaete worms and small bivalves burrowed into the sediments. Silty seafloor habitat is attractive to hermit crabs, green crabs (*Carcinus maenas*), and lobsters as well. Estimates of lobster abundance in this area based upon dive surveys in 1999 and 2001 range from 0.06-0.20 lobsters per linear meter, indicating good lobster habitat. The number of lobstermen fishing Gloucester harbor waters confirms the existence of a substantial lobster population.

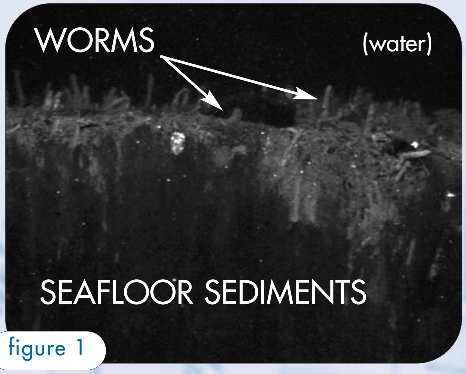


Figure 1: Inner harbor of Gloucester has a thin line of oxidized sediments (lighter colored areas on seafloor surface). Worms are an indication of a disturbed environment.

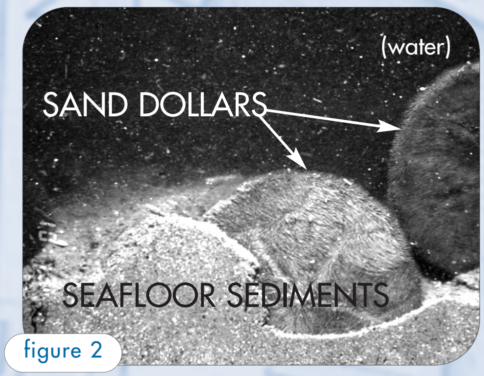


Figure 2: Outer harbor has a thicker layer of oxidized sediments, indicating a healthier seafloor environment.

Rocky Intertidal

Along the edges of Gloucester Harbor, the rocky outcrops, boulders, and tide pools form niches where numerous species can find shelter in an otherwise turbulent and energetic tidal zone. For example, a survey by the Massachusetts Audubon Society of tide pools on Eastern Point in outer Gloucester Harbor found up to 24 species in a single tide pool, including 10 species of algae; six mollusks; two species each of starfish, sea squirts, and hydroids; one species of crab; and one species of sea urchin.

Salt Marsh

Salt marshes are relatively protected and highly productive areas that provide refuge for juvenile fish and crustaceans. Salt marshes also act as biofilters for removing excessive nutrients (like nitrogen) from the waters passing through them, absorbing as much as 30 percent or more of the waterborne nitrogen entering the system from upstream. Current research is aimed at determining if the small fish that inhabit the marshes impact nutrient levels in the water column. See http://ecosystems.mbl.edu/tide/ for a study funded by the National Science Foundation that is being conducted in the Plum Island watershed and is looking at whether removing mummichogs (*Fundulus heteroclitus*), an abundant fish species, makes marshes less resistant to the effects of nutrient loading.

Sixteen acres of salt marsh occur on the western edge of Gloucester Harbor. Although the geology of the harbor shoreline is predominately exposed rock ledge and not conducive to salt marsh formation, port infrastructure such as roads and culverts have also limited its extent. To help address this issue on Eastern Point in the southeastern corner of the harbor, Massachusetts Audubon, the CZM Wetlands Restoration Program, the National Oceanic and Atmospheric Administration's Restoration Center, and the Natural Resources Conservation Service have replaced an undersized culvert to restore tidal flow to approximately six acres of formerly filled and buried tidal creek.

Submerged Aquatic Vegetation

Patches of eelgrass (*Zostera marina*—a flowering plant, not at all related to seaweed—see *Spotlight on Eelgrass* on page 19) occur on the northwestern and southeastern edges of Gloucester Harbor. Eelgrass is a productive nearshore marine habitat that supports diverse floral and faunal assemblages, absorbs nutrients, stabilizes sediments, and provides decayed matter that is consumed by species lower on the food web. A 1996 study of the eelgrass beds in Gloucester Harbor supports this characterization, finding up to 100 invertebrates, 25 bivalves, and 20 mysid shrimp per quarter of a square meter of eelgrass. This study also documented a preference of immature benthic fishes for eelgrass, finding three times as many immature fish in eelgrass beds than in unvegetated areas. The Gadidae family (pollock, cod, tomcod [*Microgadus tomcod*], and hake) made up the largest proportion of immature fish in eelgrass beds, although young winter flounder and tautog were also present.

A working port: Gloucester Harbor today is home to boats of business and pleasure, as well as native and invasive species.

Coastal Beach

Seine hauls along four Gloucester beaches in June 1999 revealed that many of the fish species found along the beaches were the same as those found in the deeper water trawls. The most noticeable and abundant addition was the Atlantic silverside (*Menidia menidia*, a common minnow), but an occasional stickleback (*Gasterosteus aculeatus*), puffer (*Sphoeroides maculatus*), or juvenile bluefish (*Pomatomus saltatrix*) was also found in the seine. These shallow areas are also visited by adult predatory fish, such as striped bass (*Morone saxatilis*), on the hunt for their crustacean or fish prey.

Port Infrastructure as Habitat

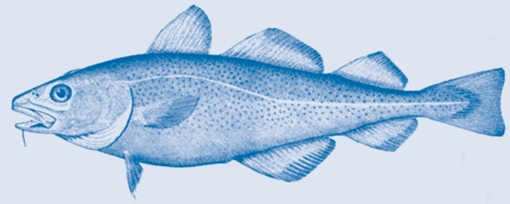
While active ports pose threats to natural habitats and the species that inhabit them, certain species of marine life continue to hang on, in some cases literally. Docks, piers, and jetties are settlement areas for a number of marine invertebrates. Walk out on a dock and take a look at the bright orange sponges and squishy sea squirts, notice the constellations of white barnacles and clumps of mussels woven together by their byssal threads. You may also see crabs or shrimp scuttling along algae-covered pilings. These encrusting and bottom-crawling communities originally inhabited only the boulders and ledges left by the receding glaciers thousands of years ago. However, these organisms can also be found on rock jetties, riprap, pilings, mooring lines, navigational aids, and some boat bottoms. The increased open space on new docks and piers creates settlement areas for entire aquatic communities. Not all new substrate has positive benefits, however. Recent scientific studies suggest that docks and piers may be unintentional promoters of invasive species. For example, a survey at the Gloucester State Pier identified at least 12 invasive species, including four tunicates, two shrimp, two crabs, a hydroid, an anemone, a bryozoan, and a red alga.

Forward into the Future

Ports are very important parts of the economic and historical landscape of Massachusetts. What is sometimes forgotten is that these busy industrial areas still contain intact and fragmented habitats that are populated by a wide variety of marine organisms. Ports do not have to be wastelands to sustain human uses, and can be managed with an eye toward maintaining and remediating the fragments of productive habitat that remain.

the other other white meat: Atlantic Cod

The Life History and Habitat Requirements of Atlantic Cod: *The Story Behind a Plate of Fish & Chips*



By Anthony R. Wilbur, CZM

The Atlantic cod (*Gadus morhua*)—a legendary fish of great economic, social, and ecological value to Massachusetts—is memorialized by a bronze statue on prominent display at the State House, honoring this staple of New England's economy for 300 years. For centuries, this prolific species drew settlers to colonize areas of North America for easy access to productive fishing grounds. Despite a long history of exploitation and the extensive study of Atlantic cod, much remains to be discovered of its habits and habitats.

The biology and ecology of fishes is an exciting area of research, not only because there are more fish species than all other vertebrates combined, but because this diversity is magnified by their range of life history and behavioral traits. Marine teleosts (bony fish) go through four general life history stages (egg, larvae, juvenile, and adult), with species showing specialized adaptations. For fish species that undergo complex life history development, larval, juvenile, and adult phases differ in almost all characteristics, including morphology, physiology, behavior, and resource requirements.

Our knowledge of most fishes is far from complete. The ecological relationships between fishes and habitat are documented in tropical systems (e.g., coral reef and mangrove marshes), temperate seagrass beds, and kelp forests. In New England, monitoring programs, such as the National Oceanic and Atmospheric Administration (NOAA) Fisheries stock assessment trawl survey, focus on large-scale patterns of fish distribution and abundance, rather than habitat associations. The role of habitat in fishery productivity has, however, gained attention in both management and scientific communities, with the identification of Essential Fish Habitat by the federal fishery management councils and the NOAA Fisheries Service (See *Essential Fish Habitat and Fishery Management* on page 37).

Habitat is not easily defined or identified, but it is widely accepted that environmental features influence the distribution, abundance, and productivity of fishes. Since more is known about Atlantic cod than most marine fishes in New England, this article summarizes the life history and habitat requirements of cod in the Northwest Atlantic Ocean (encompassing the Gulf of Maine and Georges Bank/Southward stocks), and underscores the value of marine habitat to the diversity of fishes in Massachusetts waters.

Life History and Range

Atlantic cod are part of the family of fishes known as Gadidae (the codfish family), which contains 55 species, including haddock (*Melanogrammus aeglefinus*) and pollock (*Pollachius virens*). Cod are widely distributed in the North Atlantic Ocean, extending from Greenland to North Carolina. Populations are a fraction of historic levels, with the largest concentrations remaining in Canadian waters, Georges Bank, and western Gulf of Maine.

Throughout their life history, cod inhabit a number of habitats, ranging from surface waters to the seafloor at 250 fathoms (~1,500 feet). Cod can live for 20 years and grow to an excess of 50 inches and 100 pounds. The largest cod ever recorded was caught off the Massachusetts coast at 211 pounds! Today, cod of this size are rarely, if ever, caught.

Cod are omnivorous, feeding on a variety of fishes, crabs, and clams, and the incidental plant. (Extremely strange fare has been found in some cod stomachs, including a boot!) Typically, younger cod forage on crustaceans and then eat more fish as they grow.

Cod have annual migration patterns that depend on geographic location, life history stage (e.g., spawning movements), and season, but cod typically move in relation to water temperature, swimming inshore in autumn and retreating to deeper, offshore waters as spring approaches. Cod in the Gulf of Maine follow this pattern, but cod populations off Cape Cod and southern New England not only retreat to offshore waters in the fall, they also migrate south along the mid-Atlantic coast (historically, as far south as Chesapeake Bay) and return to New England in the spring. Adult and juvenile cod tend to congregate and migrate long distances in schools, with larger and older cod leading the way. There is also evidence that certain cod populations have limited home ranges, residing in the same area for prolonged periods.

Although fishermen know where to catch adult cod, these fish have a complex life cycle and many aspects of their life history, including habitat requirements, remain to be explained. For a cod, life begins near the surface of the ocean as an egg and continues in the water column until the young juvenile settles to the seafloor, where it matures and grows. Survivorship of these early life history stages is especially important to the population status of harvestable adults.

Eggs and Larvae

Cod invest a great deal of energy in reproduction and spawn many times throughout their life, releasing millions of eggs. Spawning behavior, which evolved to give offspring an increased chance of survival (reproductive success), involves the congregation of female and male cod and links the reproductive cycle to seasonal changes in temperature and light to coincide with peak production of prey species (phytoplankton and zooplankton) that are needed for early life history development. Cod spawn in waters that limit the dispersal of eggs, such as gyres and nearshore waters. Known spawning habitat exists on the northeast peak of Georges Bank, coastal Gulf of Maine, and the eastern portion of Nantucket Shoals. In Massachusetts, northwestern Massachusetts Bay (e.g., Nahant Bay, Salem Sound, and Ipswich Bay) is a particularly important spawning area.

The author with his very own 24" "keeper." A hot pan, a little butter—voila!—dinner is served. No preservatives, no additives, no leftovers.

photo by B.M. Wilbur

Gloucester in the Days of Yore: Codfish are split and gutted prior to being salted and dried.

photo courtesy of R. Sheedy

Eggs are fertilized in the water column and receive no parental care, floating in surface waters until they hatch. They are buoyant, spherical, and transparent and hatch in eight to 60 days (depending on water temperature). Egg density is highest in late winter and early spring, but eggs are found almost year round.

When hatching, larvae break away from the egg casing, and develop at a rate dependent on water temperature (with faster development and bigger larvae generally being produced in warmer water). The period of highest mortality in cod life history occurs between hatching and larval first feeding because of extensive predation by zooplankton and starvation. To counteract this high mortality, huge numbers of eggs are released during spawning.

The first stage of larval development is the yolk sac phase. The yolk sac contains nutrition used by the larval cod while it adapts to the pelagic environment (i.e., water column). The larvae absorb the yolk and continue to grow, while they begin to look for prey (at this stage, plankton). Larval cod are initially free-floating, drifting with currents. As larvae grow, they begin to look more like juveniles and develop the ability to swim and capture prey. Larval fishes are typically not strong swimmers but can actively seek habitat conditions that improve survival and growth.

Favorable water temperature, salinity, and food availability, as well as egg quality, are critical to larval cod survivorship, growth, and subsequent metamorphosis to the juvenile stage. Studies suggest that egg quality is related to the condition and age of spawning females, with poor feeding opportunities and first-time spawners producing lower viability in eggs. Fast growth has been correlated to the presence of high plankton concentrations, and regions that congregate plankton (e.g., areas where different ocean currents collide) are valuable forage habitats. Other environmental features influence egg and larval development, such as dissolved oxygen, nutrients, turbidity, water movement, and meteorological events, but these influences are not thoroughly explained.

Juveniles

Body shape, size, and pigmentation dramatically change during larval-juvenile metamorphosis, which occurs in the water column where juveniles remain for approximately one month. Pelagic juveniles may "test" the seafloor by bouncing along the bottom to locate suitable settlement habitat—but just how juvenile cod find these important habitats is not certain. At the point of settlement to the seafloor, cod become demersal (meaning they live near the seafloor) and look like miniature adults.

Settlement is another period of high mortality. Newly settled cod are susceptible to predation from a number of piscivores—that is fish eaters (e.g., spiny dogfish [*Squalus acanthias*], winter skate [*Leucoraja ocellata*], silver hake [*Merluccius bilinearis*], and adult cod). Complex seafloor habitats that provide refuge increase survival, making habitats such as cobble, hard bottom with attached epifauna (i.e., animals living attached to the bottom such as sponges and amphipod tubes), and eelgrass beds beneficial to early life history development. Nearshore waters of Massachusetts Bay and offshore shoal areas (e.g., Jeffreys Ledge and Georges Bank) contain these important nursery habitats. Juvenile cod are, however, not limited to complex seafloor habitats, as evidenced by studies in Salem Sound and Gloucester that collected cod on less-complex mud bottoms (although survivorship may be lower without adequate cover). In addition to protection from predation, juveniles require refuge from currents and ample supply of prey. Cod use a range of complex and simple seafloor environments before they reach the adult phase. Juvenile life history is not fully understood, and more studies that describe the life history and habitat requirements of cod from the period of settlement to two years of age are needed.

Adults

Adult cod, with their characteristic whisker-like barbel on the chin, are the most familiar life stage—tugging fishing lines, filling fishermen's nets, and often ending up on a plate. The relationship between adult cod distribution and habitat is largely based on trawl data (both from research and commercial trawls), and the largest catches are made near the seafloor on rocky slopes, ledges, and hard bottom (cobble, gravel, and sand with broken shells). Cod migrate for a variety of reasons,

another angle

Essential Fish Habitat and Fishery Management

By Anthony R. Wilbur, CZM

Traditionally, fishery management has focused on controlling the level of fishing effort to reduce excess removal of fish, using management approaches such as catch quotas, gear restrictions, and closed areas. The 1996 amendments to the federal Magnuson-Stevens Fishery Conservation and Management Act broadened this focus by requiring fishery management councils and the National Oceanic and Atmospheric Administration (NOAA) Fisheries to identify and delineate Essential Fish Habitat (EFH) for all federally managed species. The EFH provisions added habitat protection to traditional management strategies, and required councils to identify adverse impacts to EFH and ensure EFH conservation and enhancement.

EFH is broadly defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." EFH is designated and described for all life stages (egg, larvae, juvenile, adult, and spawning adult), and covers finfish, shellfish, and squid species managed by the New England and Mid-Atlantic Fishery Management Councils. The process used to identify EFH, which included analyzing relative abundance by 10′ x 10′ squares of latitude and longitude and designating squares with higher relative abundance as EFH, resulted in broad EFH delineations and virtually all of Massachusetts waters were designated as EFH for some species and/or life stage.

An EFH can be designated as a Habitat Area of Particular Concern (HAPC) for a species or group of species when habitats and geographic areas are judged to be particularly important to the long-term productivity of a population or to be particularly vulnerable to degradation. The New England Fishery Management Council identified HAPC for juvenile Atlantic cod (*Gadus morhua*) on the northeast peak of Georges Bank and for Atlantic salmon (*Salmo salar*) in select rivers of Maine because of the demonstrated ecological importance of these areas to these species. A proposal for designating shallow waters of the Gulf of Maine, including Massachusetts Bays, as HAPC for juvenile cod is pending. The Massachusetts Division of Marine Fisheries provided the background information for this proposal, which included a detailed assessment of cod's relative abundance and distribution and demonstrated that juvenile cod consistently inhabit coastal waters of Massachusetts.

EFH has heightened the awareness of the value of habitat, and in many cases increased evaluation standards for habitat alteration projects in the Massachusetts coastal zone, and elsewhere, to limit impacts to important fishery habitats. The use of the EFH provision is in its early stages, but fishery and coastal resource managers are beginning to supplement traditional management approaches with habitat protection measures to foster sustainable fisheries.

such as to spawn and locate prey, and during these annual movements they inhabit a variety of other habitats, ranging from deep-water mud basins and boulder reefs to the upper water column. Studies show a preference for structured seafloor landscapes, but the use of habitats varies and a full understanding of the ecological function of particular seafloor habitats is not thoroughly described.

Extensive commercial exploitation has changed population characteristics of Atlantic cod. Not only are populations at or near historic lows (although there are promising data demonstrating that Gulf of Maine cod populations are increasing), but cod currently mature at 1.7 to 2.3 years compared to 5.4 to 6.3 years in 1959. Because larger fish produce more eggs, today's population of smaller spawning adults may produce fewer eggs (lower fecundity) than in the past. Compounding this situation, the selective removal of harvestable fish (i.e., fish of sufficient size to be captured by conventional fishing gear) also removes their genes from the population, resulting in depressed genetic diversity for cod in future generations.

Summary

Despite Atlantic cod being one of the most intensively studied fish species in Massachusetts waters, many questions remain about their life history and habitat requirements. Although overfishing has substantially depressed populations, the effect of habitat degradation warrants attention. Atlantic cod populations have supported fishing communities for more than 300 years, but the current population may not sustain this important local industry. While there are promising data indicating that management measures are helping Atlantic cod populations, a multifaceted approach that includes understanding the life history, habitat requirements, and ecology of fishes is required to manage fisheries and habitats.

Most of the cod life history and habitat characteristics information is summarized in:

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Eek Gadus morhua! Cod this size were once plentiful. This one is probably more than 10 years old and hopefully indicates that cod populations are on the rebound.

photo by Brandy

Lough, R.G., P.C. Valentine, D.C. Potter, P.J. Auditore, G.R. Bolz, J.D. Neilson, and R.I. Perry. 1989. Ecology and distribution of juvenile cod and haddock in relation to sediment type and bottom currents on eastern Georges Bank. *Marine Ecology Progress Series* 56:1-12.

Habitat Found: What's Good for the Gull's NOT Good for the Plover *By Anne Donovan, CZM*

When you think of coastal and marine habitats, you probably don't think of landfills. In fact, this unfortunate byproduct of the human habitat certainly does not seem hospitable to anything in nature. But, although these burial grounds for refuse undermine property values in most residential neighborhoods, they are highly prized real estate for one of our most adaptable native birds, the Herring Gull (*Larus argentatus*).

Profile of the Herring Gull

The Commonwealth's most typical "seagull," the Herring Gull is a noticeable year-round Massachusetts resident, and is recognized from here to Alaska, summering, wintering, and/or migrating through every state in the United States, except Hawaii.

photo by Arden Miller

This graceful aerial acrobat of Jonathan Livingston fame is a beauty, whether found at the shore or in a parking lot. It takes four years for a Herring Gull to reach maturity, and before that it goes through nine different plumages, confounding amateur bird watchers with a slate of feather variations ranging from mottled browns and grays to whites. The adult bird is two feet long with wingspan of almost five feet, has an electric-white body, gray wings with black tips, pinkish-tan legs, and a yellow beak, complete with a bright red spot at the tip (which gives gull chicks a cue as to where to peck for a regurgitated meal).

Herring Gulls live up to 20 years in the wild and feed on a varied and adaptable diet. Natural food sources include: mussels, crabs, fish (live or dead), sea urchins, carrion (dead animals), insects, eggs, chicks, and even the occasional adult tern or plover. Gulls never pass up an easy meal, however, and large portions of their diet come from garbage, bait and fish waste, table scraps of all kinds, and even sewage. With such a profound capacity to utilize human food sources, the only Herring Gulls that currently still dine on an exclusively natural diet are found on far offshore islands or in remote parts of the low Arctic. Herring Gulls also bring new meaning to "eating on the run" and are capable of consuming their entire daily food intake in 15 minutes flat.

Each pair of Herring Gulls, which tend to mate for life, raises one brood a year, although they will lay new eggs if they lose their original eggs or chicks. They build rough nests out of whatever is available, including sticks, grass, feathers, moss, and even trash and other discards. The female typically lays three eggs, which can vary dramatically from mother to mother in color, size, and shape. Chicks take from 24 to 28 days to hatch, are capable of flight in about 45 days, and then stay with their parents for another month.

Habitat—More than a Place to Call Home

For a habitat to provide all that Herring Gulls need to survive, it must include places to feed, nest, roost at night, and "loaf." Before the bounty of landfills and other human food sources, the gulls' habitat was tied to the coast. Similar to suburban sprawl, however, Herring Gull breeding range has extended inland, following the landfill food source. In fact, in Massachusetts, gulls exploiting landfill leftovers now nest as far inland as the Quabbin Reservoir in the central part of the state, using this and other inland reservoirs for drinking and bathing.

One of the few constants with Herring Gulls is that they always nest near water. Generally, they nest in colonies on islands or rock outcroppings. When nesting offshore, they frequently set up housekeeping on flat ground, while mainland nesters favor cliffs, probably to avoid predatory mammals. In some places where human food sources are abundant, they have begun to nest on roofs and window ledges of buildings. (At CZM, we witnessed this behavior first-hand when several pairs of this adaptable bird species built nests on an open wall of a high-rise being reconstructed directly across from our eighth-floor Boston office.)

When it comes to nesting, Herring Gulls are communal. They nest in colonies and return to the same place year after year to breed and raise young. Aggression is often the key to breeding success, and pairs will staunchly defend their nest sites from neighbors. If there is a threat from outside, however, the entire colony of gulls will band together to attack a potential predator.

Because of their long lifespan and commitment to nesting territories, Herring Gull breeding colonies are virtually permanent once established. As the population in a successful colony expands to fill the available territory, however, young birds are left with no place to nest. These young adults start loafing near a food source, ultimately nesting along a nearby waterbody when their urge to breed takes over. This is the start of a new colony that can expand over time to fill this available territory, assuming the food source is sufficient.

Like humans, Herring Gulls are willing to commute, which further expands their range. This commuting capacity was actually studied near Boston in 1961 and 1962 when researchers caught and tagged breeding birds with colorful paint. The gulls were then followed to determine how far they flew in search of food. Not surprisingly most foraged as close as possible to the breeding colony. To exploit choice food sources such as landfills, however, a certain segment of the population was willing to commute great distances, and even a 50 mile round trip was routine.

The Human Impact on the Herring Gull through History

At one time, the human was not the friend of the Herring Gull. In the 1800s, local fishermen and farmers were eager to supplement their larders with eggs of easy-to-gather ground nesters, including the Herring Gull. (Our resourceful gull did not entirely take this "lying down." In an 1833 visit to Grand Manan, John Audubon noted that the local gull population had taken to nesting in fir trees—and island residents confirmed that these birds had previously nested on the ground.) The situation worsened for the gull and its brethren in the 1880s when fashionable women began wearing feathers in their hats. To satisfy this fad of the time, herons, gulls, egrets, and terns were hunted almost to extinction. In fact, in 1890, the state of Maine actually established a sanctuary for the "endangered Herring Gull" on Great Duck and Little Duck Islands (near Mt. Desert Island). The plight of these birds also spurred the Audubon Society into existence in 1890, with this group successfully bringing the feathers-for-hats slaughter to an end.

Once protected, human habitation and habits became a boon for the Herring Gull. These resourceful scavengers first found an abundant food supply in the discards of fishermen and the fishing industry. But the real gravy train was yet to come…

The Landfill Windfall

Beginning in the mid-1950s, open landfills became a commonplace smorgasbord for the scavenging gull. The result was a population explosion, with Herring Gulls reaching a peak population of 110,000 breeding pairs on the U.S. Atlantic Coast in the late 1970s (up from their relative obscurity at the turn of the century). Since this heyday, the closing of landfills has resulted in a slight decline of population levels (100,000 breeding pairs on the U.S. Atlantic Coast as of the early 1990s).

Despite the current dearth of landfills, good times continue for the Herring Gull. The adaptability of this species and the abundant food supply available through other human-based sources, including trash cans and lobster bait, provide a continued competitive advantage for the species. Even its traditional feeding techniques have been enhanced. When once a young gull learned to crack a mussel on a rock, today's young learn to use the endless supply of pavement. In addition, the European green crab (*Carcinus maenas*), a species likely introduced to Massachusetts waters through international shipping activities, has become a widespread and easily caught intruder that greatly supplements gull diets. Some individuals have even been found to specialize on French fries, hanging out by fast-food dumpsters to snag a high-fat meal.

Good for the Gull, Bad for the Neighbors

While on the surface enhancing habitat of a native and formerly overly exploited species may seem like a good thing, inevitably, the interference of the human world with the natural cascades into a string of unforeseen consequences. For example, this bloated population of Herring Gulls causes problems for the humans that caused it. Birds loafing on reservoirs foul water supplies with their droppings and have the potential to transmit disease. While flying near airports or otherwise in a flight path, these large birds can pose a threat to aviation.

(In the spirit of full disclosure, gulls are not always a nuisance to people. In addition to providing eggs and feathers, gulls have been known through history to help humans. In Germany, for instance, Herring Gull populations were protected because of the abundant fertilizer they provided. Grateful Mormons' have also erected the Sea Gull Monument in Utah after a flock of gulls swooped in to gobble up a plague of crickets that had decimated the Mormon's crops in 1848-49.)

Too many gulls also come at the expense of a variety of birds that compete for oceanfront nesting sites, including the threatened Piping Plovers (*Charadrius melodus*) and endangered Roseate Terns (*Sterna dougallii*), as well as Common Terns (*S. hirundo*), which, despite their name, are considered a "species of special concern" in the Commonwealth (which means if their population decline continues, they will become threatened species). Herring Gulls nest earlier than terns and plovers, and this, combined with their size and outright aggression gives them a distinct advantage in the battle for nesting sites. The other birds are forced into less desirable locations where they are more susceptible to predators, further from food sources, and otherwise less capable of successfully raising young. The gull's capacity to eat almost anything also gives them a foraging advantage, allowing them to successfully raise more hungry chicks than the plovers and terns with their pickier palates. In addition, these gulls are successful predators, taking the eggs and chicks of neighboring seabirds (including other Herring Gulls), further reducing the populations of scarcer species.

Finally, with the Piping Plover, the very presence of the potentially predatory gull can cause them to pack up and move on.

To address this human-induced problem, wildlife managers are trying to provide gull-free nesting areas for the struggling terns and plovers. On Monomoy Island in Chatham, for example, the U.S. Fish & Wildlife Service (USFWS) executed an extremely successful campaign to carve out an 80-acre section of the northern tip of South Monomoy for other birds, particularly terns. In 1996, USFWS staff dropped poison-soaked bread into gull nests, killing 5,000 birds, outraging many animal rights activists, residents, and local officials. For the terns, the effort paid off. Common Terns went from 200 breeding pairs in 1995 to 8,700 by 2003. Populations of Roseate Terns, Laughing Gulls, and Piping Plovers on the island are also improving with the reduced gull pressure.

A flock of seagulls—Herring Gulls, not the band—flock to the pier in Gloucester in hopes of catching some crustacean snacks.

Conclusion: If You Build It, They Will Come (But Others Will Go)

Clearly, the development and resource use associated with the human habitat has a profound effect on the animals and plants that also call Massachusetts and its coastal and ocean areas home. In most cases, this land use diminishes and destroys wildlife habitat, but sometimes, like with the Herring Gull, an adaptable species is actually at a competitive advantage because of its ability to cohabitate with humans. The resulting population increase is not a wildlife management success story, however, because it generally occurs at the expense of other species that are not only competing with the successful cohabitators, but also struggling in the face of habitat diminished by human development. These population explosions tend to come at a cost to humans as well, and the heyday of the Herring Gull is no exception, with the resulting threats to drinking water quality and aviation safety. The lessons from our history with the Herring Gull show that the constant motion created by our actions has significant and cascading impacts, benefiting some species sometimes, while harming others.

Precious Cargo: Shipwrecks as Habitat

By Dave Trubey, CZM's Board of Underwater Archaeological Resources

FOR MANY PEOPLE, THE MENTION OF A SHIPWRECK CONJURES UP FANCIFUL IMAGES of trunks filled with gold, silver, and precious jewels. In reality, while the vast majority of wrecks contain no such material rewards, they are frequently overflowing with the glittering treasures of another sort—tales of maritime history, places of interest for scuba divers, and habitats that can support a variety of marine life.

With an estimated 2,000 shipwrecks off the Massachusetts coast—ranging in size from small dories to freighters of more than 400 feet in length—wrecks are often full of colorful stories of past lives and times. And, over time, they can develop into colorful homes for a variety of fish, mollusk, and plant species.

photo by Tom Mulloy

What draws particular creatures of the sea to these ruins? This question is a subject of debate and research for many experts within the marine community. Part of the answer, it is believed, lies in the way that the wreck structure itself changes seafloor conditions, in turn attracting a range of marine creatures that would not otherwise seek to make this area their home. With the initial onset of a wreck, an existing seafloor and its inhabitants can be destroyed by the impact alone. If the ship is carrying hazardous materials, or is made from composites inhospitable to existing sea life, marine inhabitants' lives can be significantly degraded. Some immediately, some over time. Once the ship and its contents settle, previously established current and sedimentation patterns are changed, sometimes drastically. Existing marine life can be displaced, and the habitat it depended on can be forever changed.

But once the seafloor settles, in place of the displaced, a new underwater microcosm takes root. On a basic level, shipwrecks, be they fairly intact or a wreck of a wreck, increase in the available surface area where certain species of marine organisms can eat, breathe, and reproduce. Wrecks can also provide a complex interface with the water column (i.e., the area between the seafloor and the ocean surface) where marine plants and animals that require topographic heterogeneity and hardened structure can colonize and thrive.

Another benefit for some species is the way in which shipwrecks can diffuse strong currents and create pockets of calm water where schools of fish can rest and plankton-rich eddies can form. These conditions are particularly desirable for certain types of fishes in their early stages of development as they can congregate and feed without disruption.

In the shallower waters along the New England coast, creatures such as anemones, mussels, and barnacles are quick to colonize and the transformation of a shipwreck into an environment that supports these marine organisms may take less than a season. Given more time, these areas in turn can attract sea life that is drawn to these assemblages, resulting in an environment desirable to these marine organisms and the divers who love them.

Of particular note to divers, the numerous crevices, cracks, and nooks of the ship's wreck provide refuge for smaller fish and other creatures that may be hiding from their predators. A well-placed beam from a diver's light will often reveal the surprised eyes of a finned critter anxiously awaiting the departure of its unexpected guest. In addition to these spectacular views, these sites often make for very productive fishing grounds. For decades, fishermen have recognized the correlation between "hangs" (bottom obstructions, often times shipwrecks, on which fish nets frequently snag) and an abundance of fish, particularly sea bass and cod. For nautical archaeologists, shipwreck researchers, and divers, the locations of these hangs or "hang data" have become a significant tool for locating uncharted wrecks.

To give a brief example, the schooner barge *Winsor* was located using hang data in 1993. Once discovered, it could be ascertained that this vessel was constructed in 1923 by the Kelley-Spear Company of Bath, Maine, and measured 202.9 feet in length and 38.1 feet across its beam, and drew 16.5 feet of water. Further investigation revealed that, in 1946, while carrying 1,800 tons of coal from New York to Boston, the vessel was lost during a particularly powerful December blizzard. Today, the remains of *Winsor* rest off Marshfield, Massachusetts, and serve as a remarkable marine habitat for a variety of species including cod, wolfish, goosefish, sea raven, cunners, anemones, and sea urchins.

The *Winsor* is one of the known wrecks where the habitat benefits have been verified; we suspect countless habitats exist with treasures yet to be discovered. For better or for worse, when it comes to shipwrecks, one species loss can be another's gain.

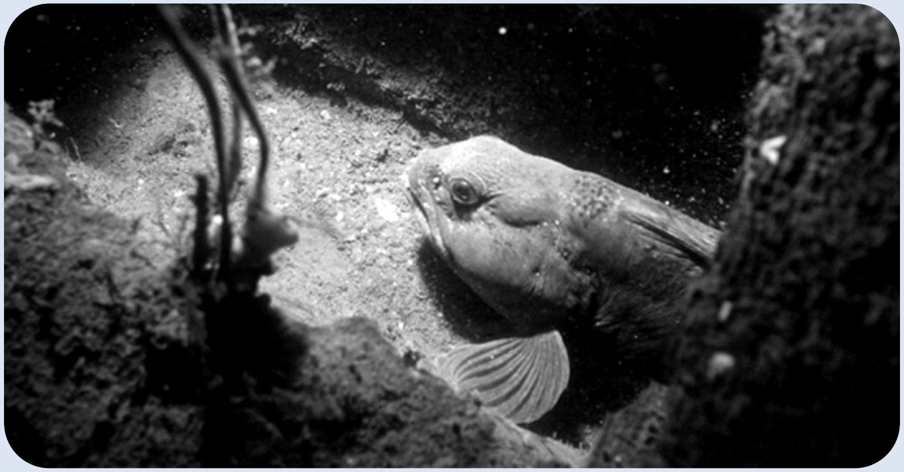

photo by Tom Mulloy

Hide and seek! Fish, such as this wolfish, often seek shelter in the remains of wrecks. This particular wreck is located off Marshfield.

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